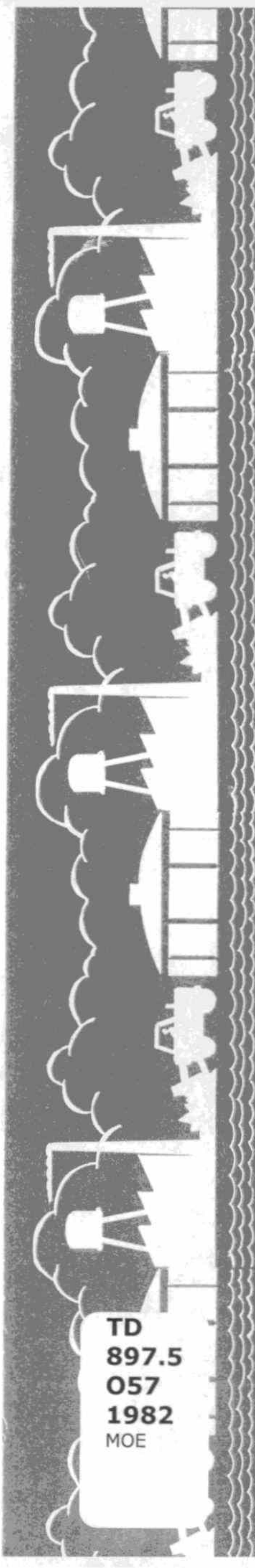

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# PROCEEDINGS

## 29th Ontario Industrial Waste Conference

June 13 – 16, 1982
The Prince Hotel
Toronto, Ontario

TD
897.5
O57
1982
MOE

Ministry
of the
Environment
Ontario

Hon. Keith C. Norton, Q.C.,
Minister

Gérard J. M. Raymond
Deputy Minister

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# Proceedings
# of the
# Twenty - ninth
# Ontario Industrial Waste Conference

held at

The Prince Hotel
Toronto, Ontario

June 13 -16, 1982

Sponsored by the
Ontario Ministry of the Environment

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Air Quality Assessment Unit
Ontario Ministry of the Environment
Don Mills, Ontario

## ONTARIO INDUSTRIAL WASTE CONFERENCE HISTORICAL DATA

| **Location** | **Dates** | **Sponsor** |
|---|---|---|
| Ontario Agriculture College, Guelph | 1954 to 1956 | Pollution Control Board of Ontario |
| Delawana Inn, Honey Harbour | 1957 to 1963 | Ontario Water Resources Commission Water & Pollution Advisory Committee |
| Bigwin Inn, Lake of Bays | 1964 & 1965 | Ontario Water Resources Commission Water & Pollution Advisory Committee |
| Park Motor Hotel, Niagara Falls | 1966 & 1967 | Ontario Water Resources Commission |
| Sheraton Brock Hotel, Niagara Falls | 1968 to 1971 | Ontario Water Resources Commission |
| Skyline Hotel, Toronto | 1972 to 1974 | Ontario Ministry of the Environment |
| The Prince Hotel, Toronto | 1975 to 1982 | Ontario Ministry of the Environment |

| **Conference Chairman** | **Dates** | **Secretary/ Co-Ordinator** |
|---|---|---|
| Dr.A. E. Berry | 1954 to 1962 | D. S. Caverly/M. Grove |
| D. S. Caverly | 1963 to 1973 | L. M. Tobias |
| K. H. Sharpe | 1974 to 1976 | M. J. Cathcart (1974) |
| D. P. Caplice | 1977 & 1978 | |
| J. W. Giles | 1979 to 1982 | M. F. Cheetham- 1975 to 1982 |

**Program Conveners**

| | |
|---|---|
| 1960-1973 | F. A. Voege |
| 1974-1978 | J. B. Patterson |
| 1979-1982 | R. C. Stewart |

# PREFACE TO THE PROCEEDINGS OF THE 29th ONTARIO INDUSTRIAL WASTE CONFERENCE

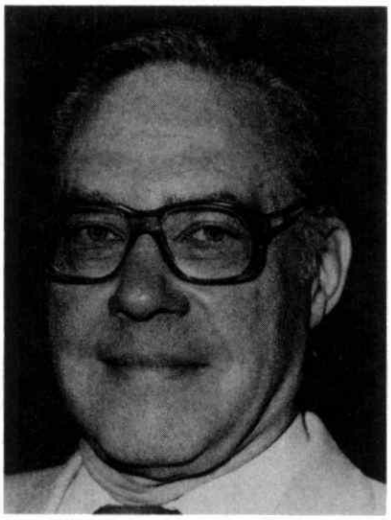
The Conference Planning Committee and the Technical Program Committee express their appreciation to all those who contributed to the success of the 29th Ontario Industrial Waste Conference. We surpassed the 500 attendance objective for the seventh consecutive year with 532 participating in the 1982 Conference, a most creditable representation considering the economic climate at the present time.

The success of every Conference depends on the program, how it is conceived and it's execution. A particular thanks to the Program Committee for re-introducing "the plumbing papers" for this year's Conference. From the interest, attendance, and comments, all were well received and appreciated by the delegates  A special thanks to the authors for their conscientious preparation and delivery, and to the session moderators for their excellent chairmanship and the management of their program segment. This combination made the 1982 Conference one of the most favourably commented upon in recent years. The contents of these Proceedings will demonstrate why.

The Conference sponsor, the Ontario Ministry of the Environment, thanks each delegate for their registration and participation in the 29th Conference. This support enables us to continue to attract high calibre papers, stimulating speakers, capable session moderators; all of which combine to make the Ontario Industrial Waste Conference one of the premier conferences to attend during the year. Our 30th annual Conference will be held at the Prince Hotel in Toronto, June 12 - 15, 1983 inclusive. You are invited and we look forward to another rewarding idea and information exchange on topics relating to industrial abatement, pollution control and waste management. Interest your business associates, and bring your spouse. There's no better "conference package" in Canada when you consider investment and return. See you in '83 !

J. Walter Giles,
Conference Chairman

# CONFERENCE PLANNING COMMITTEE



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J. W. Giles
Associate Deputy Minister
Intergovernmental Relations and
Strategic Projects
Ontario Ministry of the Environment

Program Convener
R. C. Stewart
Manager Technical Support
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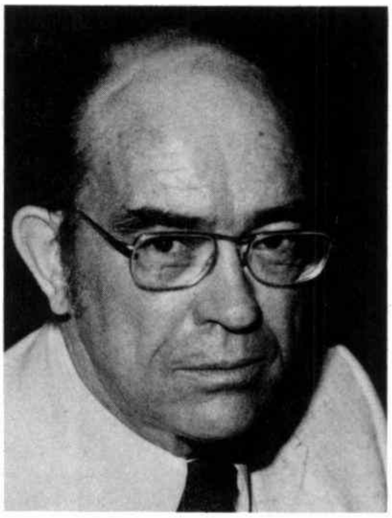
Ontario Ministry of the Environment



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Ontario Ministry of the Environment

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Hazardous Contaminants and
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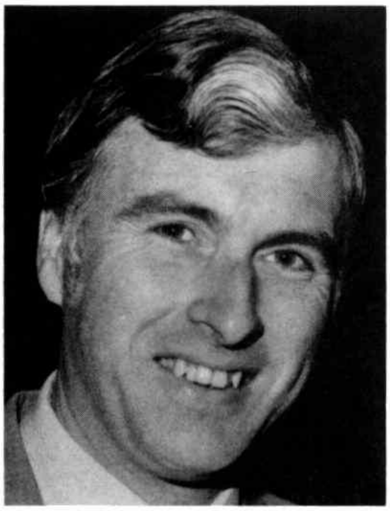

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Water Resources Branch,
Environment Ontario

P. Kupa, Head
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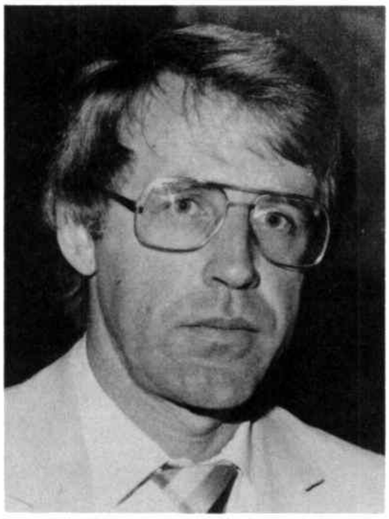
Environmental Assessment Unit
Air Resources Branch,
Environment Ontario

# THE PAPERS AND THE AUTHORS

at the

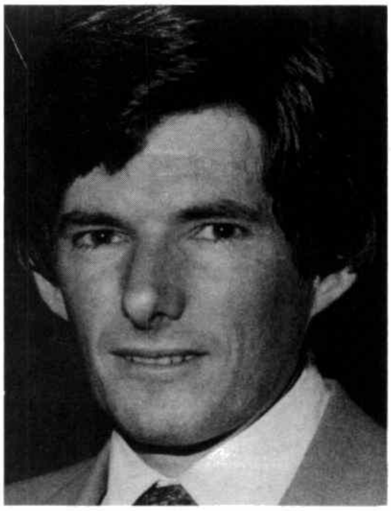
# 29TH ONTARIO INDUSTRIAL WASTE CONFERENCE JUNE 1982

# SESSION I - PERSPECTIVES ON SOLID WASTE MANAGEMENT

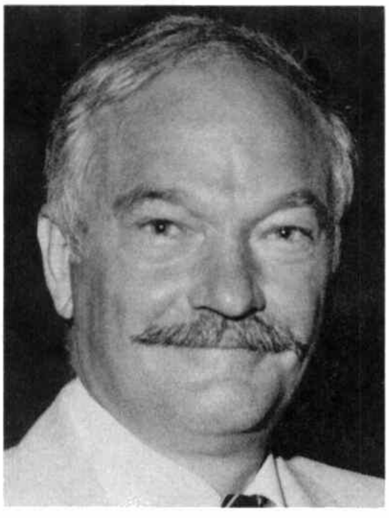


**Chairman:** T. D. Armstrong
Co-ordinator
Waste Disposal Site Program
Waste Management Branch,
Environment Ontario

Her Worship, Mayor C. Miller
City of Cambridge
Cambridge, Ontario



Michael Keating
Editorial Department
The Globe and Mail
Toronto, Ontario



Jim Temple, District Manager
Waste Management of Canada Inc.
Weston, Ontario

# PERSPECTIVES OF SOLID WASTE MANAGEMENT

## PUBLIC PERSPECTIVES

Mayor C. Miller
City of Cambridge
Cambridge, Ontario

Her Worship spoke from notes and did not have a formal text. Consequently, no formal paper is available for inclusion in the Proceedings.

## Media Perspectives

# WASTE MANAGEMENT AND THE NEWS MEDIA: INFORMATION OR MANIPULATION

by
Michael Keating, Editorial Department
The Globe and Mail
Toronto, Ontario

YOU HAVE ALL SEEN THE HEADLINES....

"PCB POISONS BUILD UP IN THE BODY."

"MISSISSAUGA COULD BECOME PCB DUMP, MAYOR ASSERTS."

"BYLAW PASSED DEFYING PARROTT OVER PCB TEST."

"TOXIC WASTES: TIP OF THE ICEBERG."

"TOWN FIGHTS PLAN FOR TOXIC WASTE TREATMENT PLAN."

"LACK OF PLANNING FOR DISPOSAL CRISIS MAY LEAD TO SHUT DOWNS IN INDUSTRY."

"AJAX WASTE SITE GETS GO-AHEAD, REVIEW PROCESS CALLED A SHAM."

"INDUSTRIES CITED FOR DUMPING HAZARDOUS WASTES."

"DUMP IS POISON, HAMILTON WOMAN WARNS."

"U.S. REPORT CITES ILLNESS FROM POISONS AT FALLS DUMP."

THESE ARE JUST A FEW OF THE HEADLINES CULLED FROM MY FILES ON WASTE MANAGEMENT AND THEY COME NOT FROM WHAT IS SOMETIMES CALLED THE SENSATIONALIST PRESS BUT FROM THE MORE SOBER AND SERIOUS JOURNALS IN THREE COUNTRIES.... THE GLOBE AND MAIL, INCLUDING THE REPORT ON BUSINESS SECTION, FROM THE NEW YORK TIMES AND THE NEW SCIENTIST OF GREAT BRITAIN.

NOTICE THE KEY WORDS IN THOSE HEADLINES... TOXICS, HAZARDOUS, POISON, DUMP, WASTES, CRISIS, INDUSTRY AND GOVERNMENT.

LET ME RE-ASSEMBLE THEM SLIGHTLY AND WRITE MY OWN HEADLINE. IT SAYS, "THE MEDIA SEES A CRISIS IN CONFIDENCE OVER GOVERNMENT AND INDUSTRY HANDLING OF TOXIC WASTES."

I SUSPECT MOST OF YOU WOULD AGREE THAT IS A WIDELY HELD PUBLIC VIEWPOINT EVEN IF YOU DIDN'T ALL AGREE THAT IT WAS AN ACCURATE ONE.

LIKE YOU I HAVE WATCHED THE EVOLUTION OF THE TOXIC WASTES DEBATE, THE ROLE OF THE NEWS MEDIA, THE REVELATION OF MORE AND MORE INFORMATION AND THE DEVELOPMENT OF PUBLIC OPINION ON THE SUBJECT.

RACHEL CARSON' BOOK, SILENT SPRING, PUBLISHED 20 YEARS AGO, LAUNCHED THE GREAT DEBATE ON TOXIC CHEMICALS AS MUCH AS ANY SINGLE EVENT. DURING THAT DECADE CASES LIKE THE DYING OF LAKE ERIE HEIGHTENED PUBLIC CONCERN ABOUT POLLUTION.

THE MERCURY SCARE OF 1970 FOCUSSED PUBLIC ATTENTION ON TRACE CONTAMINANTS AS A REAL AND SERIOUS HEALTH THREAT. THIS WAS FOLLOWED BY THE DISCOVERY OF MIREX AND PCBS AND LATER DIOXIN.

THE DISCOVERY OF LOVE CANAL IN 1977 BROUGHT HAZARDOUS CHEMICAL WASTE DUMPS TO THE FORE AS A SEPARATE ISSUE WITHIN THE OVERALL DEBATE ON INDUSTRIAL POLLUTION.

THIS WAS QUICKLY FOLLOWED BY ACID RAIN WHICH WAS DESCRIBED AS AN EVEN GREATER THREAT TO OUR ENVIRONMENT.

TOXICS BECAME A COMMONLY USED WORD AS SCIENCE AND INDUSTRY COMBINED TO START DETECTING THE MANY TRACE CONTAMINANTS IN OUR AIR AND WATER AND ALL THIS WAD

DULY REPORTED IN THE NEWS MEDIA.

IN THE PAST THERE HAD BEEN MANY LOCAL DEBATES ABOUT DUMPING BUT MOST OF THEM CENTRED ON THE DISPOSAL OF MUNICIPAL WASTES.

BUT IN THE LAST DECADE THE PUBLIC IN CANADA, AND PARTICULARLY IN ONTARIO WITH ALL ITS INDUSTRY, HAS BECOME WORRIED ABOUT TOXICS IN THE ENVIRONMENT AND THE QUESTION WAS: WHERE ARE THE POISONS COMING FROM? THE ANSWER WAS PRETTY OBVIOUS. THEY WERE COMING FROM INDUSTRIES AND INDUSTRIAL DUMPS.

PEOPLE, INCLUDING REPORTERS AND EDITORS, LOOKED TO GOVERNMENTS TO SOLVE THE PROBLEM. IN THIS CASE IT IS A PROVINCIAL GOVERNMENT RESPONSIBILITY BUT RECORD OF GOVENMENTS HAS BEEN VERY SPOTTY.

FOR EXAMPLE ONTARIO'S ENVIRONMENT MINISTRY COMMISSIONED THE MCLAREN REPORT WHICH WAS RELEASED WITH MUCH FANFARE IN THE FALL OF 1979.

THEN THE GOVERNMENT PUT ITS FOOT IN IT BY DESIGNATING THE SOUTH CAYUGA SITE. THE NEWS MEDIA JUMPED ON THIS CASE WITH CHARGES THAT POLITICAL OPPORTUNISM WAS TAKING PRECEDENCE OVER PUBLIC INTEREST.

THE GOVERNMENT HAD THE BAD LUCK TO BE WRONG IN ITS AND AS A RESULT WE HAVE LOST THREE YEARS IN THE BATTLE TO FIND BETTER DISPOSAL SITES FOR HAZARDOUS WASTES.

AS A SIDE EFFECT THE PUBLIC HAS BECOME EVEN MORE SUSPICIOUS OF GOVERNMENTS' HANDLING OF THE WASTE DISPOSAL ISSUE.

THERE HAS BEEN ONE CASE OF ANOTHER OF FAILED ATTEMPTS TO DISPOSE OF WASTES:

PCB BURNS IN MISSISSAUGA CARRIED OUT WITHOUT PUBLIC CONSULTATION AND THE COUNCIL THEN BANS ANY FURTHER ATTEMPTS AT DISPOSAL.

ATTEMPTS TO PUT A WASTE DISPOSAL PLANT INTO AJAX AND AT ONE POINT THE HEARING PANEL WAS OVER-RULED WHEN IT SAID THIS WAS A BAD IDEA, BUT FINALLY THE GOVERNMENT SCRAPPED THE PLAN.

PLANS TO STORE PCBS IN MIDDLEPORT SHELVED AFTER PUBLIC OPPOSITION, THE WALKER BROTHERS QUARRY CASE, THE RIDGE LANDFILL CASE AT CHATHAM AND, OF COURSE, THE

LATEST CASE IS THE STOUFFVILLE DUMP.

IN EACH CASE THE NEWS MEDIA HAS PLAYED A CRUCIAL ROLE IN DEFINING THE ISSUES IN THE PUBLIC EYE.

HAVE WE IN THE MEDIA BEEN ACCURATE OR HAVE WE BEEN MANIPULATED?

I WON'T TRY TO TALLY UP THE POINTS FOR EACH SIDE. IT'S BEYOND MY RESOURCES TO ANALYZE ALL THE MANY NEWS MEDIA-- NEWSPAPERS, RADIO AND TELEVISION-- AND THEIR STORIES.

I THINK ANY ANALYSIS WOULD FIND A PATCHWORK OF STORIES CARRYING OPINIONS FROM BOTH SIDES OF THE DEBATE BUT GENERALLY POINTING OUT THE FEARS OF THE CITIZENS AND VOICING SUSPICION OF GOVERNMENT AND INDUSTRY.

SOME OF YOU MIGHT ACCUSE THE NEWS MEDIA OF SIDING WITH THE CITIZENS WHILE IN FACT WHAT YOU ARE DEALING WITH IS THE GENERAL PRACTICE OF THE MEDIA IN REPORTING EVENTS.

REPORTERS AND EDITORS WILL USUALLY LISTEN TO ANYONE WHO SEEMS TO HAVE A STORY TO TELL.

IN THE CASE OF WASTE DISPOSAL THE SCENE WAS SET FOR CITIZENS TO GET A SYMPATHETIC HEARING FROM THE PRESS. THERE HAD BEEN ENOUGH CASES OF INDUSTRIES AND GOVERNMENTS FAILING TO PROPERLY DISPOSE OF OR REGULATE DISPOSAL OF WASTES THAT THE SEEDS OF SUSPICION WERE SOWN IN THE MINDS OF THE PUBLIC.

THEN WE WERE CONFRONTED BY WHAT APPEARED TO BE UNDERDOGS... ORDINARY CITIZENS, MOTHERS WITH CHILDREN IN THEIR ARMS, FARMERS, LAWYERS EVEN SOME POLITICIANS. THEY WERE ALL SINGING THE NOW FAMILIAR SONG... NOT IN MY BACKYARD YOU DON'T. YOU ARE NOT GOING TO POISON US WITH YOUR FOUL, INDUSTRIAL WASTES.

SO WE HAVE A CLASSIC CONFRONTATION SITUATION, ONE WHICH ALMOST INEVITABLY LEADS TO A NEWS STORY.

ON ONE SIDE INDUSTRY SAYS WE CAN'T AFFORD BETTER DISPOSAL OR IT IS NOT AVAILABLE TO US OR THE WASTES ARE NOT PROVEN HARMFUL IN ANY CASE.

GOVERNMENTS SAY WE HAVE TO PUT THESE WASTES SOMEWHERE.

THE PEOPLE SAY, WE ARE A RURAL COMMUNITY AND WE DIDN'T GENERATE THE WASTES SO WHY SHOULD WE TAKE THEM. AND IN ANY CASE, PROVE THAT YOU ARE NOT GOING TO POISON US AND CAUSE BIRTH DEFECTS AND CANCER WITH CHEMICALS LEAKING INTO OUR DRINKING WATER.

THE NEWS MEDIA ARE LEFT TO TRY TO SORT OUT CONTRADICTORY AND CONFUSING BITS OF INFORMATION.

IN MOST STORIES REPORTERS AND EDITORS, WHO ARE BASICALLY ORDINARY PEOPLE WITH ORDINARY INTELLIGENCE AND A LOT OF GENERAL EXPERIENCE IN LIFE, HAVE PREDEDENTS TO WORK FROM.

IT IS EASY TO SEE A BODY LYING ON THE STREET AND CONCLUDE THAT MURDER WAS COMMITTED.

WE CAN COMMENT FROM OUR PERSONAL EXPERIENCE ABOUT THE PROS AND CONS OF DECISIONS BY INDUSTRY AND GOVERNMENT ON AGRICULTURE, CONSTRUCTION, TRANSPORTATION AND MILITARY HARDWARE.

BUT WHEN IT COMES TO EVAULATING THE EFFECTS OF PARTS PER BILLION OF A CHEMICAL WHOSE NAME MOST OF US CAN'T EVEN PRONOUNCE WE ARE SAILING INTO UNFAMILIAR TERRITORY.

WE TURN TO SCIENTISTS FOR THE ANSWERS AND OFTEN FIND THEY DISAGREE AMONG THEMSELVES ON THE ULTIMATE EFFECT OF TOXICS AND ON HOW MUCH IS DANGEROUS. ANYONE WHO SPENDS TIME QUESTIONING THE EXPERTS ON HOW THEY SET SAFE LEVELS IS TOLD THEY ARE EDUCATED GUESSES.

WE DEPEND ON HYDROGEOLOGISTS TO TELL US WHETHER THE CHEMICALS WILL LEACH THROUGH THE SOIL AND ROCK AND INTO OUR DRINKING WATER. SOMETIMES THEY DISAGREE.

SO WE FALL BACK ON THE TRADITIONAL APPOACH AND REPORT WHAT ALL SIDES ARE SAYING.

AND THE CITIZEN'S GROUPS HAVE SHOWN AN EVER-INCREASING SOPHISTICATION ABOUT HOW TO GET THEIR VIEWPOINT INTO PRINT AND ONTO THE AIR.

IN SOME CASES I WOULD SAY A HOUSEWIFE IS DOING A BETTER PUBLIC RELATIONS JOB FOR HER SIDE THAN GOVERNMENTS AND INDUSTRIES WHO HAVE INFORMATION DEPARTMENTS COSTING HUNDREDS OF THOUSANDS OF DOLLARS.

WHAT ARE THE MECHANICS OF GETTING THE STORIES TO THE PUBLIC?

A NEWS OPERATION CONSISTS OF A SERIES OF REPORTERS, EDITORS AND PHOTOGRAPHERS. LOOKING AT THE HIERARCHY OF A NEWSPAPER FOR EXAMPLE YOU HAVE THE EDITOR OF THE PAPER AT THE TOP OF THE NEWS OPERATION. THE EDITOR IS RESPONSIBLE FOR THE OVERALL NEWS CONTENT THOUGH ON A LARGE PAPER HE OR SHE WILL NOT BE INVOLVED IN THE DAY-TO-DAY CHOICE OF MOST OF THE STORIES.

THE EDITOR IS IN DIRECT CHARGE OF THE EDITORIAL PAGE WHICH IS THE OPINION PAGE OF THE NEWSPAPER AND IS SEPARATED FROM THE NEWS SIDE.

THEN YOU HAVE THE NEWS DEPARTMENT A GROUP OF REPORTERS AND EDITORS WHO COLLECT AND EDIT THE NEWS STORIES IT IS IN THIS DEPARTMENT YOU ARE MOST LIKELY TO FIND AN ENVIRONMENT SPECIALIST SUCH AS MYSELF.

IN ADDITION YOU MAY HAVE A FEATURE DEPARTMENT IN THE PAPER, WHICH WILL ASSIGN WRITERS TO DO LONGER STORIES ON ISSUES, INCLUDING POLLUTION. IN FACT THERE MAY BE SOME OVERLAP BETWEEN WHAT A FEATURE WRITER DOES AND WHAT A NEWS REPORTER DOES.

IN THE TELEVISION AND RADIO STATIONS YOU USUALLY DO NOT HAVE AN EDITORIAL DEPARTMENT BECAUSE HISTORICALLY THEY HAVE NOT GIVEN THEMSELVES AN EDITORIAL SLOT IN THE DAY FOR THE SENIOR EDITOR TO EXPRESS HIS OPINIONS. HOWEVER YOU WILL GET SOME CASES OF NEWS PERSONALITIES HIRED TO AIR THEIR PERSONAL OPINIONS ON A VARIETY OF ISSUES.

IN GENERAL STORIES OF ALL KINDS ARE PROVIDED BY A SERIES OF MEANS.

ONE OF THE MAIN SOURCES OF INFORMATION ARE GOVERNMENTS EITHER THROUGH THEIR PUBLIC DEBATES OR THROUGH STORIES THEY DELIBERATELY RELEASE TO THE MEDIA. MEMBERS OF THE PUBLIC OR PUBLIC INTEREST GROUPS OR PEOPLE IN INDUSTRY WILL ALSO CALL UP THE NEWS MEDIA WITH PIECES OF INFORMATION THEY WANT TO SEE MADE PUBLIC.

AND REPORTERS BUILD UP SOURCES OF INFORMATION AND KEEP ASKING QUESTIONS WHICH OFTEN LEAD TO STORIES .

LETS TAKE A TYPICAL STORY INVOLVING WASTE DISPOSAL.

THE SCENARIO USUALLY STARTS WITH INDUSTRY OR GOVERNMENT OR BOTH ANNOUNCING THAT THEY ARE PLANNING TO CREATE OR EXPAND A WASTE DISPOSAL SITE. THIS WILL PROBABLY LEAD TO A FAIRLY STRAIGHTFORWARD STORY ANNOUNCING THE PLAN.

THE LOCAL CITIZENS READ THE ANNOUNCEMENT AND DECIDE THIS IS A BAD DEAL FOR THEM.

SOMEONE CALLS THE PRESS AND THAT STARTS THE BALL ROLLING FOR THE OPPOSITION. THE CALLER MAY EXPRESS ANYTHING FROM A VAGUE CONCERN TO A WELL-DOCUMENTED BEEF, COMPLETE WITH CITATIONS FROM SCIENTIFIC JOURNALS.

A FEW OF THE MAGIC WORDS ARE SPOKEN AND THE REPORTER OR EDITOR WHO GOT THE CALL STARTS WONDERING IF THERE IS A STORY HERE.

THERE IS ALREADY A STORY IN THE FACT THAT THE SITE IS ANNOUNCED AND SO THE OPPONENTS ARE GIVEN THEIR SAY AS PART OF THE JOURNALISTIC PRINCIPLE THAT BOTH SIDES OF A CASE DESERVE TO BE HEARD.

I CAN TELL YOU FROM PERSONAL EXPERIENCE THAT WITH WASTE DISPOSAL SITES THE INFORMATION IN THE DEBATE CAN VERY VERY UNSATISFYING FOR THE REPORTERS AND EDITORS WHO ARE TRYING TO MAKE NEWS JUDGMENTS AS THEY GO. IT'S ALL VERY WELL TO SAY THERE ARE TOXIC CHEMICALS INVOLVED BUT IN MANY CASES WE CANNOT GET A CLEAR IDEA OF THE MAGNITUDE OF THE THREAT.

PEOPLE THROW IN STORIES ABOUT MISCARRIAGES AND CANCER IN A CERTAIN AREA AND ATTRIBUTE THAT TO A NEARBY TOXIC DUMP OR SOME PESTICIDE SPRAYING PROGRAM. NO ONE KNOWS WHAT THE REAL ANSWER IS SO THE NEWS MEDIA CARRY THE ALLEGATIONS AND WE HAVE TO LEAVE IT TO PEOPLE TO MAKE UP THEIR OWN MINDS ABOUT CAUSE AND EFFECT.

IN THE CASE OF STOUFFVILLE I THINK IT IS INTERESTING THAT THE CITIZENS

OPPOSING EXPANSION OF THE DUMP DELIBERATELY USED FEAR AS A WEAPON. "BETTER PANICKED THAN DEAD," THEY SAID OF THEIR CAMPAIGN.

I THINK THE MOST ACCURATE SUMMARY I CAN MAKE OF NEWS MEDIA ATTITUDES IS THAT WE ARE TENDING TO ERR ON THE SIDE OF CAUTION. IF WE SUSPECT THERE IS A HUMAN HEALTH PROBLEM WE WILL SAY SO.

NOW I'M NOT GOING TO CLAIM THAT NEWS STORIES ARE RESPONSIBLE FOR CANCELLING WASTE DISPOSAL PROJECTS IN ONTARIO BUT I'M SURE THE PRESS HAD AN IMPORTANT ROLE IN THE DECISIONS.

SO WHERE ARE WE GOING IN THE FUTURE ON WASTE DISPOSAL AND WHAT IS THE ROLE OF THE NEWS MEDIA?

A FEW YEARS AGO THE GOVERNMENT TOLD US THERE WAS A CRISIS. WE WERE RUNNING OUT OF SPACE TO DUMP OUR CHEMICAL GARBAGE AND WE HAD TO FIND NEW SITES TO REPLACE THE OLD ONES.

THEN WE SAW A SERIES OF FALSE STARTS.

FINALLY THE PROVINCIAL GOVERNMENT DID WHAT IT SHOULD HAVE DONE IN THE FIRST PLACE, OR AT LEAST WHAT IT SHOULD HAVE CONTINUED TO DO FOLLOWING THE MCLAREN REPORT. IT CALLED FOR A REASONED STUDY OF ALL THE ALTERNATIVES AND FULL PUBLIC DISUCSSION.

IT HAS CREATED THE ONTARIO WASTE MANAGEMENT CORPORATION TO DEFUSE THE SITUATION BY CARRYING OUT DETAILED RESEARCH AND COME UP WITH NEW OPTIONS. IN A NEWS SENSE THIS HAS LED TO A COOLING-OFF PERIOD IN WHICH THERE ARE NO WINDMILLS TO TILT AT FOR THE MOMENT.

DONALD CHANT'S GROUP WILL PROBABLY SET THE TIMETABLE FOR WHEN THINGS HEAT UP AGAIN.

AS SOON AS THAT GROUP ANNOUNCES A NEW SITE OR GROUP OF SITES YOU CAN EXPECT LOCAL RESIDENTS TO SOUND A CALL TO ARMS TO PROTECT THEIR NEIGHBORHOODS. WHAT HAPPENS NEXT DEPENDS TO A GREAT DEAL ON HOW THE INFORMATION IS HANDLED AND ON THE FIRST IMPRESSIONS GIVEN TO THE PUBLIC.

IF THERE IS THE SLIGHTEST SUGGESTION OF OPPORTUNISM-- THAT SITES ARE BEING PICKED FOR ANYTHING BUT THEIR SUITABILITY FOR WASTE DISPOSAL-- THEN YOU WILL SEE A MASSIVE WALL OF RESISTANCE AND AT THE SAME TIME A FURTHER EROSION OF PUBLIC CONFIDENCE.

GOVERNMENT AND INDUSTRY MUST BE COMPLETELY CANDID IN ANNOUNCING THEIR PLANS IN THE FUTURE IF THEY ARE TO HAVE THE SLIGHTEST HOPE OF PUBLIC SUPPORT.

THERE MUST BE NO WHIFF OF A COVER-UP OF INFORMATION, NO MATTER HOW INNOCUOUS IT MAY APPEAR TO BE.

IF THE WASTES ARE HAZARDOUS IT IS CRUCIAL THAT THIS BE ADMITTED IMMEDIATELY AND THAT THERE BE NO SUGGESTION OF A COVER-UP. HISTORY HAS SHOW TIME AND AGAIN THAT COVER-UPS ARE UNCOVERED AND CREDIBILITY IS THEN DESTROYED IN THE PROCESS.

NATURALLY YOU CAN EXPECT THE NEWS MEDIA TO BE FRONT AND CENTRE IN THE DEBATE AND CALLING YOU FOR INFORMATION. I MAY WELL BE ONE OF THOSE REPORTERS.

IF YOU PUT ME OFF WITH EXCUSES WHEN I KNOW YOU HAVE THE INFORMATION THEN I WILL SUSPECT YOUR MOTIVES.

I CAN ONLY URGE YOU TO BE VERY CANDID IN YOUR DESCRIPTIONS OF WHAT YOU ARE DOING AND WHAT THE RELATIVE RISKS ARE AND TO KEEP UP AN INFORMED PUBLIC DISCUSSION. SINCE THIS IS A DEMOCRACY YOU WILL THEN LIVE WITH RESULTING DECISIONS BUT AT LEAST LET THEM BE INFORMED ONES.

# DOES BUSINESS HAVE ANY BUSINESS IN THE WASTE BUSINESS ?

by

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A hundred years from now your great-great-grandchildren are going to go down to the Royal Ontario Museum and see a likeness of me. The inscription on the pedestal will read: Homo Landfillus Privatus -- Extinct circa 1982.

However, unlike the Dodo or the carrier pigeon or even the brontosaurus, I doubt that we in the private waste management industry will be missed.

Last fall the Blenheim town council in Southwestern Ontario called for government ownership of the controversial Ridge Landfill. The councillors of that nice little farm community seem to have had it with private landfill operators. They suggested that the Ontario government set up a Waste Management Commission to oversee municipal and solid waste dumping.

The implication seemed to be that private operators were incapable of disposing of waste without somehow making a nuisance of themselves.

More recently -- in fact just a month ago -- Ontario's 13 regional chairmen said they were going to ask the Minister of the Environment Keith Norton to take full responsibility for all the landfills in Ontario.

In this case it wasn't a dissatisfaction with private enterprise that united the regional chairmen. They were upset because our landfill at Stouffville had been ordered closed -- even though the Environmental Assessment Board had recommended that we be allowed to expand our landfill working area.

The questions are: How did we arrive at such an unfortunate state of affairs in Ontario? How is it that private waste management companies are being treated as if they are what they bury? Who or what forces are we running up against that are determined to keep private enterprise out of the waste disposal business?

Is it our own mismanagement? Is there a conspiracy of bureaucrats determined to undermine our garbage empires -- so that they can reign supreme? Has mass hysteria about pollution, Love Canal and Hooker Chemical driven the public into the protective arms of government -- even though government is no more credible with environmentalists than we are? Or has the media done it all with mirrors -- which reflect only half-truths and lynch-mob rhetoric?

I've heard convincing arguments on all of those theories. Personally, I think the problem is one of social and political prejudice. Garbage, even one's own garbage, is repugnant. It excites a very strong distaste in most people.

Every individual creates half a ton of garbage every year, yet when he puts it out at the curbside he doesn't want to see it or think about it again. That prejudice against our own garbage is as at least as intolerant as the ancient Roman's feelings toward the Christians.

But to get rid of garbage you can't feed it to the lions.

And as for recycling and recovery: Well then you're really getting into the area of science fiction. North America has had its share of huge expensive failures in this area. Systems that won't work. Systems that seem to be permanently in the "shakedown" phase. Systems that are too expensive to operate. And systems that make an environmental nuisance of themselves.

In 1968 the Ontario Ministry of the Environment predicted that 85 percent of all urban waste would be recycled by 1985. But that was back in the days of flower children. Governments in those heady days were determined to be on the side of peace and making love, not war, and turning garbage into chocolate fudge. And is 85 percent of urban waste being recycled? No -- 85 percent of urban waste is being buried -- in landfills -- just like the one at Stouffville.

I don't mean to imply that we are not making progress with waste management technology. We are. And spectacularly. Many companies in North America are working on waste-to-energy technologies. And the Europeans have been successful in that area for nearly 30 years. But in Europe energy costs have been traditionally about twice as high as energy costs in North America. And there is a critical lack of space for landfills. As a result of these factors the burning of waste for energy became economical in Europe and meanwhile they've made the process environmentally acceptable.

In North America there are between 10 and 15 waste-to-energy facilities underway or planned and each of them has a good chance of success. But the installed capacity will be no more than 20,000 tons a day. In other words they'll only serve between five and ten million of the continent's 250 million people.

The other 240 million people will have to bury their garbage. There's nothing else to be done with it. Ronald Reagan and Anne Gorsuch, his administrator at the Environmental Protection Agency, had the notion that North America's garbage should be buried at sea. That was a recent suggestion. And that faint sound of thunder you hear is the stampede of environmentalists rushing to defend marine life.

What about the environmentalists? Well God bless them they changed my business from one of trucking garbage and unloading it in the town dump to one of transporting urban waste to engineered sanitary landfills. We're not just "garbage men" anymore, we're engineers and hydrogeologists and lab technicians. Government regulation -- in response to the concerns of environmentalists -- has made professionals of us. Frustrated and half-crazy professionals, perhaps, but professionals just the same.

In Ontario, the professionals from private waste disposal companies are up against enormous odds if they intend to stay in the waste disposal business.

They must first find a site. They must be convinced it can be transformed into a landfill which satisfies the unwritten standards of the Ontario Ministry of the Environment. They must satisfy the Ontario Municipal Board and a host of regional and local bylaws and statutes. They must persuade the Environmental Assessment Board that the site will be neither hazardous nor a nuisance to its neighbours. Then the Minister of the Environment -- whose decisions often reflect the advice of his ministry experts -- must be prepared to assess courageously his political and ministerial responsibilities and alight on your side of the fence.

While this is all going on of course you are likely to be set upon by neighbours and by friends of neighbours who have read about Love Canal. By that, I don't mean to trivialize the health hazards connected with the random and irresponsible unloading of toxic wastes on an unsuspecting public. But none of us here today are in that business. However, since Love Canal, even harmless household wastes are greeted with suspicion.

Three years ago we at Waste Management of Canada had high hopes that our site at Maple would be one of the grandest and most celebrated landfills in the Western World.

So far there has been very little to celebrate. First there was a very long hearing before the Environmental Assessment Board which we lost. Then a hearing before the Environmental Appeal Board, which gave us the go ahead, provided we lived up to 19 conditions. And finally there was the sale of the site to Metropolitan Toronto. I must say with a sigh that that lovely big hole in the ground has just about become the grave of our dreams for a viable private landfill business in Ontario. And Stouffville could become our headstone.

The Stouffville story is equally tragic and equally telling as far as private enterprise in the waste disposal business in Ontario is concerned.

The Whitchurch-Stouffville landfill in the 1950s was a depository for thousands of gallons of liquid industrial waste. But in this respect it was no different than many sites in Ontario, including those right here in Toronto. Those landfills all accepted large quantities of liquid industrial wastes. Some in the province still do. The difference is that the citizens of Stouffville have been made aware of the liquid wastes in their neighbouring landfill. Most communities have no idea what is in their landfills; no analysis has ever been made.

At any rate, during six weeks of last Spring and Summer, we went to an Environmental Assessment Board hearing and persuaded the Board that our management of the site at Stouffville was such that we should be allowed to expand our working area. The Board agreed and recommended to the Ministry of the Environment that we be allowed to expand. But in the background there was a band of well-organized Stouffville residents who were determined to see the site closed.

Their campaign was quite effective. For starters they announced that they suspected that the drinking water in nearby private wells was being polluted by the landfill. But the Ministry of the Environment had been testing 13 private wells around the site for 15 years and found no evidence of pollution. And for the last 11 years the Ministry has been examining the water from 22 test wells on the site without finding any evidence that the nearby private wells are threatened in any way.

But the citizens conducted their own tests of wells near the landfill and publicized their findings. Their tests indicated they had found contaminated water near the landfill. So the Ministry -- in defence of its own and its laboratory's credibility -- went to work. In three days they conducted 3,000 tests on the water on and around the landfill. Result: several definitive statements from the Minister of the Environment.

"There is absolutely no indication that the drinking waters are contaminated by the landfill or any other source."

"We found no pesticides, no PCBs, no dioxins, and no hexachlorobenzenes."

"All the water quality parameters for drinking waters were within the Ministry's water quality criteria."

With all that praise, the Minister ordered the site closed by July 1983. Ironically, the site was not ordered closed because of the health issues. The Ministry cited other reasons. None of them were convincing, as far as we were concerned, so we appealed the decision.

However, the Ministry decision does beg a question? Why go to a public hearing if the Ministry has the option not to attend or even review with care the evidence taken under oath?

Perhaps we should take a close look at the hearing process. Certainly, if the hearings are meant to take the heat out of a belligerent issue, they don't. If they're meant to give the public an opportunity to participate, they don't. If they're meant to air the technical and engineering protocols, plans, and practicalities, they do. But the ultimate decision-makers in the Ministry can choose to differ with the Board's conclusions about them.

On the first day of a hearing into a landfill, the hearing room is filled with concerned citizens and the media. On the second day, the story is in the paper and the concerned citizens and the media begin to wander away while the turgid technical details are laid out on the operating table, dissected, and quarreled over by lawyers and experts. If there is any more useless exercise it must be jogging on the way to the guillotine.

Besides the fact that the results of the hearings may have no influence on the Ministry, there seems to be no useful purpose for exploring in excruciating detail the engineering specifics of a landfill during a hearing.

Wouldn't it be laughable if every bridge, tunnel, ship hull, automobile brake lining, and cake mix had to go through a similar sideshow in the public interest? Is there any less potential for hazard in any one of those man-made projects or products? Then why should solid waste landfills be subjected to a hearing which is a methodical, but useless, public autopsy?

Even the last two Ontario Ministers of the Environment have recognized the absolute futility of the exercise. When interested members of the public demanded a hearing into the South Cayuga liquid industrial waste treatment and storage plant, Harry Parrott made it clear that he had all the information he needed, thanks to a two-year, $425,000 study prepared for him by a firm of competent consultants. No hearing was necessary.

But life isn't that simple these days. If people can't get a hearing, they can certainly be heard, and in this case they were. People Power sprang up in Haldiman-Norfolk, and Donald Chant, who now heads the Ontario Waste Management Corporation, asked for a new study. As a result Chant had to announce the site was "at best borderline" and abandon it. He now prowls the province his lantern held high looking for the perfect site and the least obstreperous neighbours, or is it the perfect neighbours and least obstreperous site. In any case he has 400,000 tonnes of hazardous waste in Ontario, all awaiting a final resting place.

And now we have Keith Norton, a likeable and sensitive lawyer from Kingston, Ontario. He too has a problem with the hearing process. The Toronto Sun has Norton saying: "public hearings are just one way people may make their views known to decision makers."

"Public hearings tend to attract the same old groups with the same old predictable views."

The Sun says "Norton suggested people wanting to have input try phone calls to open line radio shows and letters to the ministry."

I feel pretty much as the Minister does. Except that I do believe the public should have a forum where they can let the world know they do not favour a landfill in their community if that's how they feel. There should also be an opportunity for them to challenge expert opinion, if they wish. But only in areas where the technology is unproved.

The purpose of public hearings should be to decide whether or not the public interest should prevail over the prejudices of the few. Endless days spent on technical details which can be settled ahead of time merely frustrates the hearing process. In fact no hearing should be convened until the government is satisfied the project is technically sound. At that point the public can debate both the need and any possible social or human disruptions, including the likely impact on health and the environment.

In any event, in the final analysis -- private enterprise must ask, "does business have any business in the waste management business?"

Today in Ontario there are several private companies in the waste disposal business. We are well-financed, competent, and can take care of the majority of the province's waste, including hazardous wastes. Most, if not all waste technology comes from private enterprise. But we are not being allowed to use our talents and knowledge. And we certainly don't get the feeling from the provincial government that it's interested in working with us so that we can contribute more substantially than we have been allowed to do recently. If anything, we get the unshakeable feeling that the government is doing everything in its power to discourage private industry from operating in Ontario. I cannot think of a single new major waste disposal project in Ontario which is the result of private enterprise initiatives. In fact private industry is taking a smaller and smaller share of the responsibility for disposing of waste in Ontario, even though we want to do more.

We're certainly not afraid to face a fair and reasonable hearing process. In fact we welcome the opportunity to discuss our technologies and our plans, and we do accept responsibility quite proudly.

But in today's social and regulatory climate I'm afraid I would only recommend the waste management business to my children under the following conditions:

1. If there was a firm commitment by the province to work with private enterprise in establishing waste facilities in Ontario.

2. If there was an attempt by the Ministry of the Environment to establish clear and definitive regulations for the design and operation of waste disposal facilities.

3. If the government had to study and respond within a certain period of time to schemes, plans, and drawings submitted to them for approval.

4. If a uniform approach to liability insurance and post-closing funding was required for all private and public projects.

5. If the government fully and evenly enforced its regulations, even if it meant an inconvenience to a government department or agency.

6. If there was a public hearing on social impact and public opinion separate from any technical hearings on disposal methods, except where a technology may be unproved or questionable for that specific site and poses a possible health or nuisance hazard.

Otherwise I'm afraid you see before you a dying breed: the last of the private waste management professionals: homo landfillus privatus.

# SESSION II - WASTE WATER TREATMENT

**Chairman:** P. G. Cockburn
Director of Environmental
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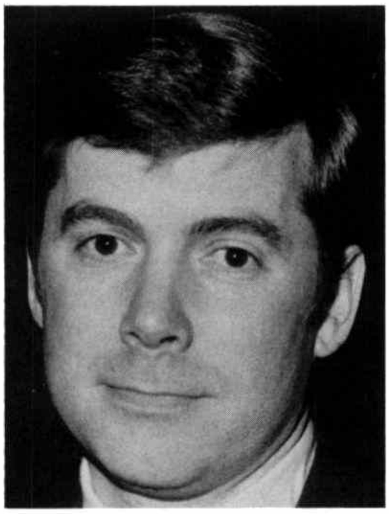

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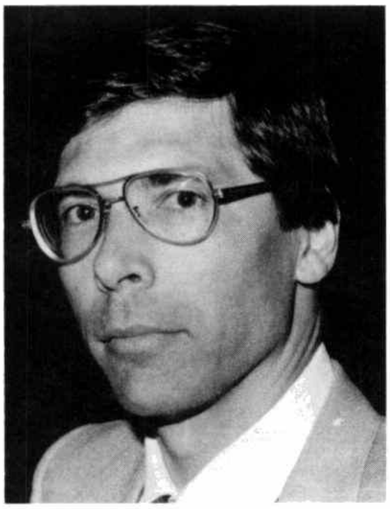

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# PILOT PLANT OPERATION OF THE INCO $SO_2$/AIR CYANIDE REMOVAL PROCESS

By

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# SUMMARY

The Inco $SO_2$/air process for cyanide removal was successfully applied on a continuous pilot scale basis to Campbell Red Lake barren solution. The process was operated for 5 weeks and consisted of two reaction stages with thickening and removal of solids between stages. Residual cyanide achieved was $<1$ mg/L $CN_T$(total cyanide) and $<0.4$ mg/L $CN_W$(weak acid dissociable cyanide) from feed containing 400 to 1000 mg/L $CN_T$. Low residual metal assays were obtained in the treated effluent including Fe at $<0.2$ mg/L. Reagent consumptions(per g $CN_T$ in the feed) were 3.8g $SO_2$ and 5.7g $Ca(OH)_2$. The use of roaster gases as the $SO_2$/air source gave excellent CN removal.

Pilot plant results were completely consistent with bench scale laboratory results on the same effluent.

Process control philosophy based on adjusting $SO_2$ addition to the first stage using redox potential as the control variable was successfully demonstrated during the pilot plant campaigns.

# INTRODUCTION

Waste effluents from a number of important industrial processes contain high levels of cyanide either as a free ion or complexed with heavy metals. For example, most of the gold produced in Canada is extracted from ore by cyanidation and effluents from gold mills need to be treated to achieve low cyanide levels before being discharged into the environment.

Various techniques for oxidizing the cyanide to cyanate using strong oxidants are reported in the literature(1-11) with some excellent reviews of the field also recently appearing(12,13). Of the methods known, only alkaline chlorination is commercially practiced. This method, however, has several serious shortcomings, namely, high reagent costs due to thiocyanate being oxidized prior to cyanide, formation of highly toxic cyanogen chloride as a reaction intermediate, contamination of the effluent by chlorine, and incomplete oxidation of the cyanide complexed with the iron, which remains in solution as $Fe(CN)_6^{-3}$ and has the potential for release of free cyanide at a later time.

A new method for oxidizing cyanide in solution has been reported by Inco Metals involving $SO_2$/air as the oxidant and dissolved Cu as a catalyst(14). The potential advantages of this process are:

- removal of both free and complexed cyanide, especially complexed with Fe, to achieve effluents containing total cyanide ($CN_T^-$) of <1 mg/l;
- very rapid kinetics at room temperature;
- low reagent consumption because $SCN^-$ is only slowly oxidized under the preferred operating conditions;
- low reagent cost because roaster gas can be used as oxidant where available or low cost elemental sulfur can be burned.

Details of successful laboratory treatment of a wide variety of Canadian gold mill effluents, both barren solutions and tailings slurries, as well as a number of other industrial waste waters, were reported in two previous publications(15,16). The next step in proving the commercial viability of the process was to increase processing scale to pilot plant size. The design, operation and results of the piloting is the focus of this paper.

The piloting was carried out at a facility constructed at Campbell Red Lake and we gratefully acknowledge the interest and help provided by the mill personnel. Operation of the pilot plant was conducted by Inco Metals personnel for a total of five weeks with the last three weeks being 24 h/day continuous mode. One of the important parts of the work was to demonstrate that the laboratory data could be scaled up for engineering design at other locations.

## SUMMARY OF PROCESS VARIABLES

The overall reaction for cyanide oxidation with $SO_2$/air is postulated to be

$$CN_T^- + SO_2 + O_2 + H_2O \rightarrow CNO^- + H_2SO_4$$

Extensive studies on a wide number of effluents have been reported previously (15,16). These studies showed that the reaction is catalyzed by copper ions in solution, presumably as $Cu^+$ in the presence of $CN^-$. The amount of catalyst necessary is somewhat variable depending on the specific effluent being treated.

The order of metal cyanide removal is Zn>Fe>Ni>Cu. The Fe cyanide complexes are reduced to the $Fe^{II}$ state by $SO_2$/air and the insoluble salts $Me_2Fe(CN)_6.xH_2O$(Me = Zn, Cu, Ni) precipitate during treatment. Following the removal of Fe in this way, the remaining Cu, Zn and Ni ultimately report to the solids as hydroxides.

The process works in the pH range of 6 to 11, but a range of pH from 9-10 is preferred for practical application. Temperature in the range 4-60°C has no significant effect on the process. $SO_2$ concentrations between 0.5 to 10 vol.% have been shown to work, but for optimum oxidation efficiency a range of 1-3 vol.% $SO_2$ in air is recommended.

Previous work on effluents containing Ni indicate that total removal of cyanide in one stage cannot be achieved because of the back-reaction of Ni solids with thiocyanate. Since Campbell Red Lake barren liquor contains Ni, both the small laboratory reactors and the pilot plant were designed with the capability of two stage operation with solids removal between stages.

## CONTINUOUS LABORATORY TESTS

### Experimental Procedure

Laboratory tests were carried out using two 0.7 liter capacity reaction vessels placed in series(Figure 1). Sulfur dioxide was added into each vessel as 2 vol.% $SO_2$ in air with most of the $SO_2$($\sim$75%) going to the first vessel. The experiments were conducted at room temperature, keeping a pH of 9 or in some cases 9.5 to 10, using a lime-water suspension (38 g/L lime). When needed copper was added as a cupric sulfate solution to the feed. The reduction-oxidation potential(Redox) versus the standard calomel electrode(S.C.E.) was monitored in each reaction vessel.

Results for Campbell effluents

A range of samples having variable compositions were studied in the laboratory apparatus. Typical results on two effluents are given in Table 1. Both of these samples contained Ni and the effect of solids removal between stages is shown for one of them.

Effluent A

This effluent was most typical of average Campbell barren with about 500 mg/L $CN_T$ and 30 to 70 mg/L of Cu, Ni, Fe and Zn(each). The effluent contained sufficient Cu for catalyzing the CN oxidation and therefore no Cu addition was made. The $CN_T$ was reduced from 500 mg/L to 20 mg/L in reactor 1. Following solids removal the second stage achieved 0.3 mg/L $CN_T$ and low metal assays. Reagent consumption was 3.1g $SO_2$/g $CN_T$ and 5.2g lime/g $CN_T$ compared to a stoichiometric requirement of 2.5g $SO_2$/g $CN_T$.

Effluent B

This effluent had an atypically high Fe content and required Cu addition to the feed. Results with and without intermediate solids removal are given in Table 1.

These results show the substantial improvement in effectiveness of the second stage when solids have been removed,as the $CN_T$ in the treated effluent was decreased from 6 mg/L to 0.6 mg/L. Low metal contents were also achieved. Overall reagent consumption was 3.0g $SO_2$/g $CN_T$.

# PILOT PLANT CIRCUIT

The pilot plant circuit comprised two 2 $m^3$ modified flotation cells(Figure 2), one 50 $m^3$ thickener and one 3 $m^3$ lime slurry tank. Liquid sulfur dioxide was delivered from one ton cylinders through $SO_2$ flowraters and injected into the air stream prior to entering each reactor. Air was delivered by a compressor and flowrate measured by differential pressure for each reactor. Maximum delivery rates were 4 $m^3$ of air and 280g of $SO_2$ per minute per reactor. Feed liquor was flowed at from 0 to 80 U.S gallons per minute. The reactors were covered with openings on one side. The gas phase above the liquor in each reactor was maintained under a slight vacuum collecting the gases into a duct connected to the plant exhaust system.

The pH in each reactor was controlled by lime slurry(40 g/L lime) added through solenoid activated red jacket valves which were connected through amplifying relays to lab Radiometer titrators. The pH was measured using Corning lab electrodes adapted to Radiometer pH meters. The lime slurry was circulated in a close loop from the stirred lime tank thereby maintaining a positive pressure to the red jacket valves. Commercial hydrated lime was used for lime slurry make up. The redox was monitored in the first reactor using laboratory Radiometer equipment.

Continuous operation without intermediate solids removal was run by cascading reactor 1(R1) directly into reactor 2(R2). When intermediate solids removal was desired, the R1 effluent was pumped to the thickener and the thickener overflow was flowed by gravity to R2. In each case R2 effluent was pumped to a tailings pond surge tank.

Copper sulfate solution(50 g/L $Cu^{++}$) was pumped into the 5.1 cm diameter feed line at an adjustable rate.

## PILOT PLANT RESULTS

### Effect of Solids Removal Between Stages

The results of two campaigns with and without intermediate solids removal are given in Table 2. During these campaigns the feed was atypically high on both $CN_T$ and Fe and the process parameters had not been fully optimized. For this atypical feed $Cu^{++}$ ion was added as a catalyst. These results compare very closely with laboratory results (Effluent B) and again show that removal of Ni-containing solids is required to achieve low residual $CN_T$.

### Use of Roaster Gases

The use of roaster gases as the oxidizing reagent was tested briefly(8 hours) during an early campaign. At the time of this testing, intermediate solids removal was not practiced. Excellent results were obtained, as summarized in Table 3, with the R2 effluent down to 1.6 mg/L $CN_T$, which were very similar to the laboratory results for high $CN_T$ feed (see Table 2). The high reactivity of hot roaster gases may account for the high $SO_2$ efficiency. Roaster gas $SO_2$ strength was not measured during the test, but we calculate that it was about 0.6 vol.% $SO_2$ on the average.

Roaster gases were not used in subsequent campaigns because they were not continuously produced at Campbell and the reliability of $SO_2$ addition rates was low for the purposes of the optimization of the pilot circuit.

Process Optimization

Our major focus during the latter campaigns was process optimization and development of control techniques. Despite having sufficient Cu already in the effluent, some Cu addition was continued to buffer possible variations in effluent composition and probable xanthate interference. Detailed results of this campaign are given in Table 4 and plotted in Figures 3 and 4 as a function of time for the 100 hrs of operation. Actual sampling was done every hour and combined in 4 hour composites. Cyanide concentrations in the feed, R1 and thickener were determined by the picric acid method which does not take into account cyanide complexed with iron. Since iron was below 0.2 mg/L at all times in R1 and the thickener, the $CN_P$ is in principle equal to $CN_T$. The $CN_T$ and weak acid dissociable cyanide, $CN_W$, were analyzed in the final effluent by a distillation technique(17). At the very low levels of cyanide achieved in this process, the cyanide analyzes performed in the plant environment are accurate only to $<1$ mg/L.

The data shown for this period can be summarized as follows:

(1) The residual $CN_T$ achieved in the treated effluent was consistently $<1.3$ mg/L with periods, often as long as 24h, of $<0.7$ mg/L. The weak acid dissociable cyanide($CN_W$) was consistently $<0.5$ mg/L and usually $<0.2$ mg/L.

(2) The Fe is essentially all precipitated in R1 down to $<0.2$ mg/L in solution.

(3) The reagent consumption was 3.8g $SO_2$ and 5.7g $Ca(OH)_2$ per g of $CN_T$ in the feed.

# PROCESS CONTROL

Results from both the laboratory and pilot plant treatment of Campbell effluent showed the necessity of removing Ni-containing solids in order to achieve the lowest residual $CN_T$. Since the final Ni is precipitated from solution after all the Fe and Zn have precipitated, the optimum two-stage process is achieved by minimizing the $CN_T$ in reactor 1. When $CN_T$ is plotted vs redox for reactor 1(see Figure 5) using all data obtained from the pilot plant and laboratory tests, a clear $CN_T$ minimum is found between +90 mV to +130 mV(S.C.E.)

The process control for Campbell effluent was to control the $SO_2$ addition rate to R1 maintaining +110 mV redox, and to have an excess of required $SO_2$ constantly added to R2. This control philosophy was tested during the last campaign at the pilot plant and was found to be valid. Other effluents will probably require a different process control strategy.

# ACKNOWLEDGEMENTS

We would like to thank the personnel at the Campbell Red Lake mill, particularly Mr. S. Reid and Mr. S. Roberts,for their cooperation and assistance during the pilot plant construction and testing program. We also thank Mr. W. Hudson of Inco Metals Engineering for his services in design and construction of the pilot facility. Particular acknowledgement goes to Mr. R. Aguis, Mr. P. Iamarino, Mr. A. Mosoiu, Mrs. B. Tandi and Mr. B. Wilson of Inco Metals staff for the operation of the pilot plant.

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14. Patent applications have been filed.

15. "New Method for Cyanide Destruction in Gold Mill Effluents and Tailing Slurries", E.A. Devuyst, V.A. Ettel and G.J. Borbely. Presented at the 14th Annual Operators Conference of the Can. Min. Proc. Div. of CIM, Ottawa, Jan. 19-21, 1982.

16. "New Process for Treatment of Waste Waters Containing Cyanide and Related Species", E.A. Devuyst, V.A. Ettel and G.J. Borbely. Presented at the AIME Annual Meeting, Dallas, Texas, Feb. 14-18, 1982.

17. "Determination of Total Cyanide in Waste waters Samples Containing Large Concentrations of Copper, Iron, Sulphide and Thiocyanide", J.R. Knechtal, K. Kon. Water Technology Centre, Environmental Protection Service, Burlington , Ontario.

# TABLE 1

## LABORATORY TWO STAGE CONTINUOUS RESULTS

| Intermediate Solids Removal | Stream | pH | Redox (SCE) (mV) | Analyses (mg/L) | | | | | | Reagents Added (g/g $CN_T$) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | $CN_T$ | $SCN^-$ | Cu | Ni | Fe | Zn | $Cu^{++}$ | $SO_2$ | Lime |
| Yes | Feed A | 9.5 | -230 | 500 | 279 | 55 | 53 | 66 | 53 | - | - | - |
| | R1 | 9.0 | +50 | 20 | 190 | 24 | 14 | 0.6 | <.2 | - | 2.28 | 3.24 |
| | R2 | 10.0 | +50 | 0.3 | 178 | 0.2 | 0.6 | 0.2 | <.2 | - | 0.85 | 1.63 |
| No | Feed B | 11.1 | -50 | 940 | 230 | 39 | 20 | 118 | 63 | 0.13 | - | - |
| | R1 | 9.0 | +120 | 12 | - | 1.8 | 6.8 | 1.0 | <.2 | - | 2.71 | 3.79 |
| | R2 | 9.5 | +140 | 6.4 | 170 | 0.2 | 1.2 | 1.6 | <.2 | - | 0.90 | 1.26 |
| Yes | Feed B | 11.1 | -50 | 940 | 230 | 39 | 20 | 118 | 63 | 0.15 | - | - |
| | R1 | 9.0 | +145 | 10 | 175 | 11 | 3 | <.2 | <.2 | - | 2.71 | 3.86 |
| | R2 | 10.0 | +80 | 0.7 | 176 | 0.6 | 0.4 | 0.2 | <.2 | - | 0.27 | 1.27 |

## TABLE 2

## PILOT PLANT TWO STAGE CONTINUOUS RESULTS

| Intermediate Solids Removal | Stream | pH | Redox (SCE) (mV) | Analyses (mg/L) | | | | | Reagents Added (g/g $CN_T$) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | $CN_T$ | Cu | Ni | Fe | Zn | $Cu^{++}$ | $SO_2$ | Lime |
| No | Feed | 9.5 | - | 780 | 54 | 36 | 94 | 76 | 0.13 | - | - |
| | R1 | 9.0 | +90 | 37 | 24 | 14 | 3 | <0.2 | - | 3.5 | 5.3 |
| | R2 | 9.5 | - | 12 | 2 | 5 | 0.7 | <0.2 | - | 0.5 | 0.8 |
| Yes | Feed | 10.5 | - | 900 | 57 | 33 | 87 | 78 | 0.11 | - | - |
| | R1 | 9.0 | +80 | 53 | 50 | 4 | 6 | <0.2 | - | 3.0 | 4.5 |
| | R2 | 10.0 | - | 2 | 2 | <0.5 | <0.5 | <0.2 | - | 0.4 | 0.6 |

## TABLE 3

## PILOT PLANT TWO STAGE CONTINUOUS RESULTS USING ROASTER GASES WITHOUT INTERMEDIATE SOLIDS REMOVAL

| Stream | | Analyses (mg/L) | | | | | Reagents Added (g/g $CN_T$) | | |
|---|---|---|---|---|---|---|---|---|---|
| | pH | $CN_T$ | Cu | Ni | Fe | Zn | $Cu^{++}$ | $SO_2$ | Lime |
| Feed | 9.5 | 890 | 55 | 35 | 80 | 35 | - | - | - |
| R1 | 9.0 | 10 | 8.0 | 7.4 | 0.2 | <0.2 | 0.09 | (1.5)* | 2.3 |
| R2 | 9.5 | 1.6 | 0.4 | 1.6 | 0.4 | <0.2 | 0.02 | (0.7) | 1.1 |
| | | | | | | | 0.11 | (2.2) | 3.4 |

* $SO_2$ consumption was estimated from lime consumed. The actual vol. % $SO_2$ for the roaster gas was not measured.

## TABLE 4

## PILOT PLANT TWO STAGE CONTINUOUS CYANIDE REMOVAL RESULTS

| TIME (h) | FEED Analyses (mg/L) | | | | | | REACTOR 1 Analyses (mg/L) | | | | | | | | THICKNER Analyses (mg/L) | | | | | | REACTOR 2 Analyses (mg/L) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $CN_p^-$ | $CNS^-$ | Cu | Ni | Fe | Zn | $CN_p^-$ | $CNS^-$ | Cu | Ni | Fe | Zn | $\frac{SO_2}{CN_p^-}$ (g/g) | Redox (+mV) SCE | $CN_p^-$ | $CNS^-$ | Cu | Ni | Fe | Zn | $CN_T^-$ | $CN_W^-$ | $CNS^-$ | Cu | Ni | Fe | Zn |
| 0 | 654 | - | 63 | 55 | 14 | 105 | 27 | - | 15 | 14 | <.2 | 7 | 4.73 | 215 | 21 | - | 28 | 11 | <.2 | 7 | 0.4 | 0.09 | - | 1 | <.2 | <.2 | <.2 |
| 4 | 680 | - | 62 | 53 | 15 | 96 | 41 | - | 4 | 22 | " | 5 | 4.55 | 203 | 35 | - | 25 | 13 | " | 6 | 0.4 | 0.09 | - | 1 | <.2 | <.2 | <.2 |
| 8 | 630 | - | 63 | 54 | 14 | 105 | 27 | - | 7 | 13 | " | 4 | 4.91 | 188 | 32 | - | 16 | 17 | " | 7 | 1.0 | 0.12 | - | 0.5 | 2 | <.2 | <.2 |
| 12 | 590 | - | 62 | 56 | 15 | 105 | 39 | - | 4 | 21 | " | 7 | 5.24 | 165 | 32 | - | 11 | 20 | " | 10 | 1.0 | 0.12 | - | 1 | 3 | <.2 | <.2 |
| 16 | 600 | - | 57 | 52 | 12 | 95 | 43 | - | 5 | 24 | " | 8 | 5.15 | 193 | 37 | - | 8 | 21 | " | 10 | 1.0 | 0.12 | - | 0.5 | 3 | <.2 | 0.5 |
| 20 | 610 | 165 | 55 | 57 | 13 | 118 | 40 | 135 | 4 | 25 | " | 7 | 5.07 | 198 | 37 | 130 | 8 | 23 | " | 11 | 1.0 | 0.12 | 115 | 0.5 | 3 | <.2 | 0.5 |
| 24 | 660 | - | 57 | 60 | 15 | 105 | 66 | - | 4 | 40 | " | 10 | 4.27 | 211 | 41 | - | 7 | 30 | " | 12 | 1.0 | 0.12 | - | 4 | 3 | <.2 | <.2 |
| 28 | 664 | - | 62 | 61 | 14 | 96 | 38 | - | 8 | 21 | " | 5 | 3.36 | 99 | 40 | - | 8 | 28 | " | 11 | 1.0 | 0.12 | - | 0.5 | 3 | <.2 | 1 |
| 32 | 644 | 170 | 57 | 62 | 20 | 95 | 10 | 140 | 12 | 8 | " | 4 | 3.10 | 88 | 34 | 140 | 8 | 22 | " | 8 | 1.1 | 0.46 | 127 | <.5 | 0.5 | <.2 | <.2 |
| 36 | 640 | - | 63 | 57 | 20 | 95 | 12 | - | 9 | 11 | " | 4 | 3.13 | 133 | 18 | - | 8 | 15 | " | 8 | 1.1 | 0.46 | - | <.2 | 0.5 | <.2 | <.2 |
| 40 | 600 | - | 67 | 57 | 21 | 95 | 25 | - | 7 | 15 | " | 3 | 3.34 | 163 | 17 | - | 6 | 14 | " | 7 | 1.1 | 0.46 | - | <.2 | 0.5 | <.2 | <.2 |
| 44 | 550 | - | 67 | 60 | 25 | 74 | 9 | - | 15 | 11 | " | 2 | 3.64 | 123 | 7 | - | 7 | 14 | " | 3 | 1.1 | 0.46 | - | <.5 | 0.5 | <.2 | 0.2 |
| 48 | 550 | 175 | 76 | 68 | 32 | 74 | 4 | 145 | 10 | 7 | " | 1 | 3.38 | 113 | 5 | 150 | 5 | 12 | " | 3 | 1.3 | 0.34 | 132 | <.2 | .2 | <.2 | <.2 |
| 52 | 590 | 182 | 89 | 72 | 35 | 102 | 10 | 155 | 26 | 9 | " | 2 | 3.08 | 110 | 2 | 150 | 13 | 11 | " | 2 | 1.3 | 0.34 | 130 | <.5 | 0.2 | <.2 | <.2 |
| 56 | 500 | - | 61 | 62 | 33 | 80 | 62 | - | 5 | 29 | " | 2 | 3.64 | 168 | 20 | - | 24 | 11 | " | 4 | 1.3 | 0.34 | - | 2 | <.5 | <.2 | <.2 |
| 60 | 530 | - | 76 | 68 | 37 | 99 | 70 | - | 4 | 37 | " | 3 | 3.43 | 190 | 45 | - | 15 | 23 | " | 5 | 1.2 | 0.21 | - | [8][a] | [3][a] | <.2 | <.2 |
| 64 | 490 | - | 71 | 66 | 37 | 99 | 60 | - | 5 | 34 | " | 2 | 3.71 | 190 | 51 | - | 10 | 31 | " | 5 | 1.2 | 0.21 | - | [6] | [8] | <.2 | <.2 |
| 68 | 530 | - | 59 | 57 | 34 | 84 | 51 | - | 3 | 28 | " | 2 | 3.43 | 200 | 50 | - | 7 | 31 | " | 3 | 1.2 | 0.21 | - | [3] | [8] | <.2 | <.2 |
| 72 | 410 | - | 53 | 45 | 35 | 62 | 34 | - | 6 | 17 | " | 0.5 | 4.16 | 182 | 42 | - | 6 | 31 | " | 2 | 1.2 | 0.21 | - | [3] | [6] | <.2 | <.2 |
| 76 | 330 | - | 46 | 42 | 28 | 65 | 41 | - | 1 | 23 | " | 1 | 4.41 | 186 | 31 | - | 4 | 22 | " | 1 | 1.2 | 0.21 | - | [2] | [4] | <.2 | <.2 |
| 80 | 390 | - | 57 | 40 | 35 | 76 | 40 | - | 15 | 20 | " | 2 | 2.68 | 161 | 42 | - | 3 | 22 | " | 3 | 1.2 | 0.21 | - | [1] | [3] | <.2 | <.2 |
| 84 | 470 | - | 63 | 44 | 39 | 69 | 34 | - | 34 | 10 | " | 1 | 2.22 | 132 | 39 | - | 23 | 18 | " | 2 | 0.6 | 0.6 | - | [13] | <.5 | <.2 | <.2 |
| 88 | 490 | - | 53 | 36 | 42 | 63 | 73 | - | 80 | 10 | " | 0.5 | 2.78 | 75 | 34 | - | 39 | 10 | " | 2 | 0.6 | 0.6 | - | [22] | <.5 | <.2 | <.2 |
| 92 | 520 | - | 48 | 28 | 39 | 56 | 30 | - | 36 | 5 | 1 | 0.1 | 3.49 | 90 | 33 | - | 60 | 5 | " | 0.2 | 0.6 | 0.6 | - | [31] | <.2 | <.2 | <.2 |
| 96 | 560 | - | 43 | 34 | 36 | 71 | 2 | - | 8 | 7 | <.2 | 1 | 2.92 | 125 | 11 | - | 34 | 2 | " | 1 | 0.7 | 0.19 | - | 1 | 0.2 | <.2 | <.2 |
| 100 | 560 | - | 41 | 26 | 35 | 65 | 2 | - | 12 | 4 | " | 1 | 2.92 | 110 | 3 | - | 20 | 3 | " | 1 | 0.7 | 0.19 | - | 1 | <.2 | <.2 | <.2 |

CONDITIONS:
FEED : $Cu^{++}$ added in line.
R1 : pH 9, $SO_2$ added: variable (see Table)
THICKNER: pH 8.3,
R2 : pH 9.8, $SO_2$ added: 0.79 g/L feed

[a] These high metal assays due to inefficient filtering or slow hydrolysis. Samples allowed to stand for 1 day typically analyzed <1 mg/L metal.

FIGURE 1

LABORATORY CONTINUOUS SET UP

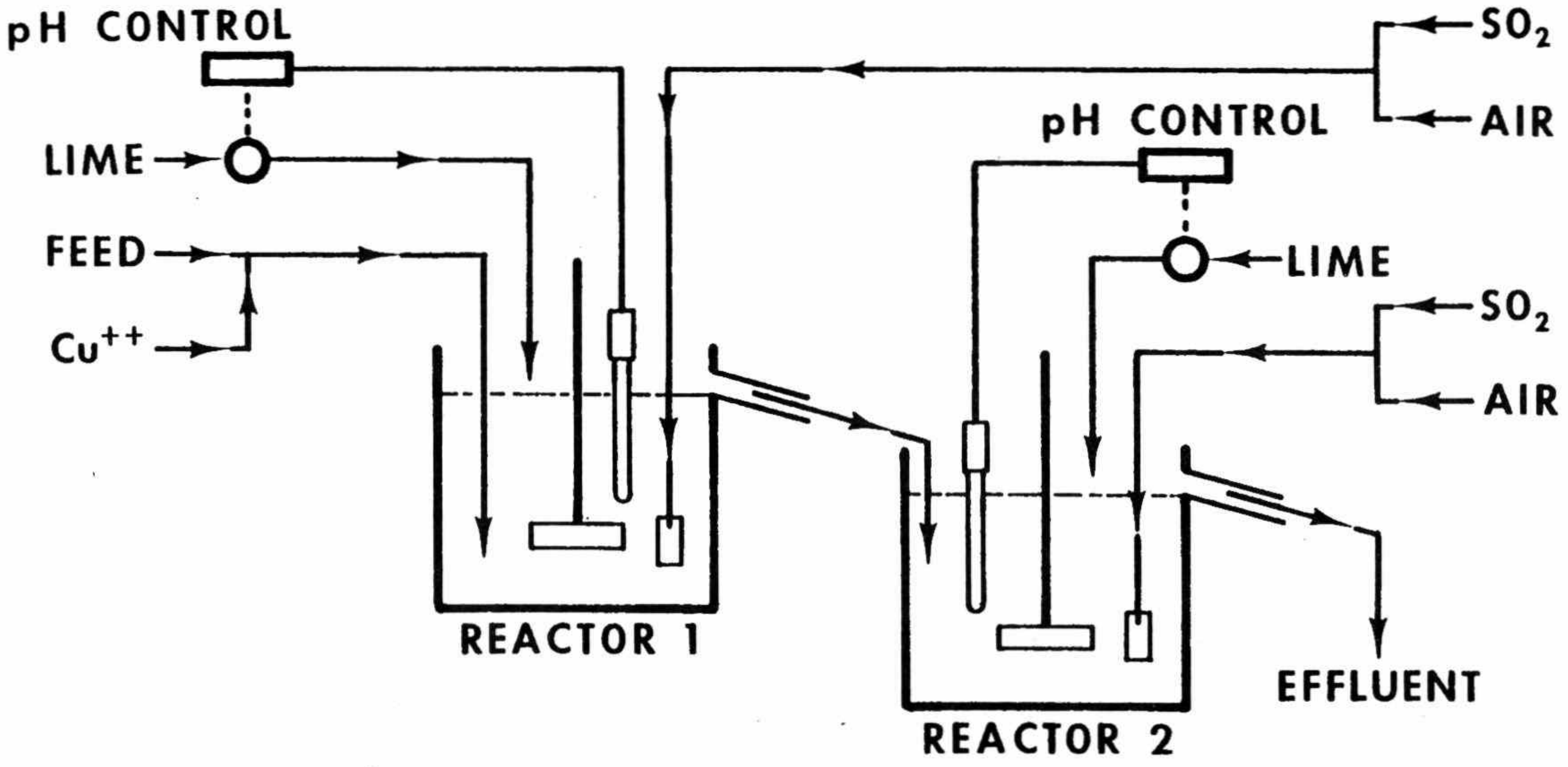


FIGURE 2

# PILOT PLANT FLOWSHEET

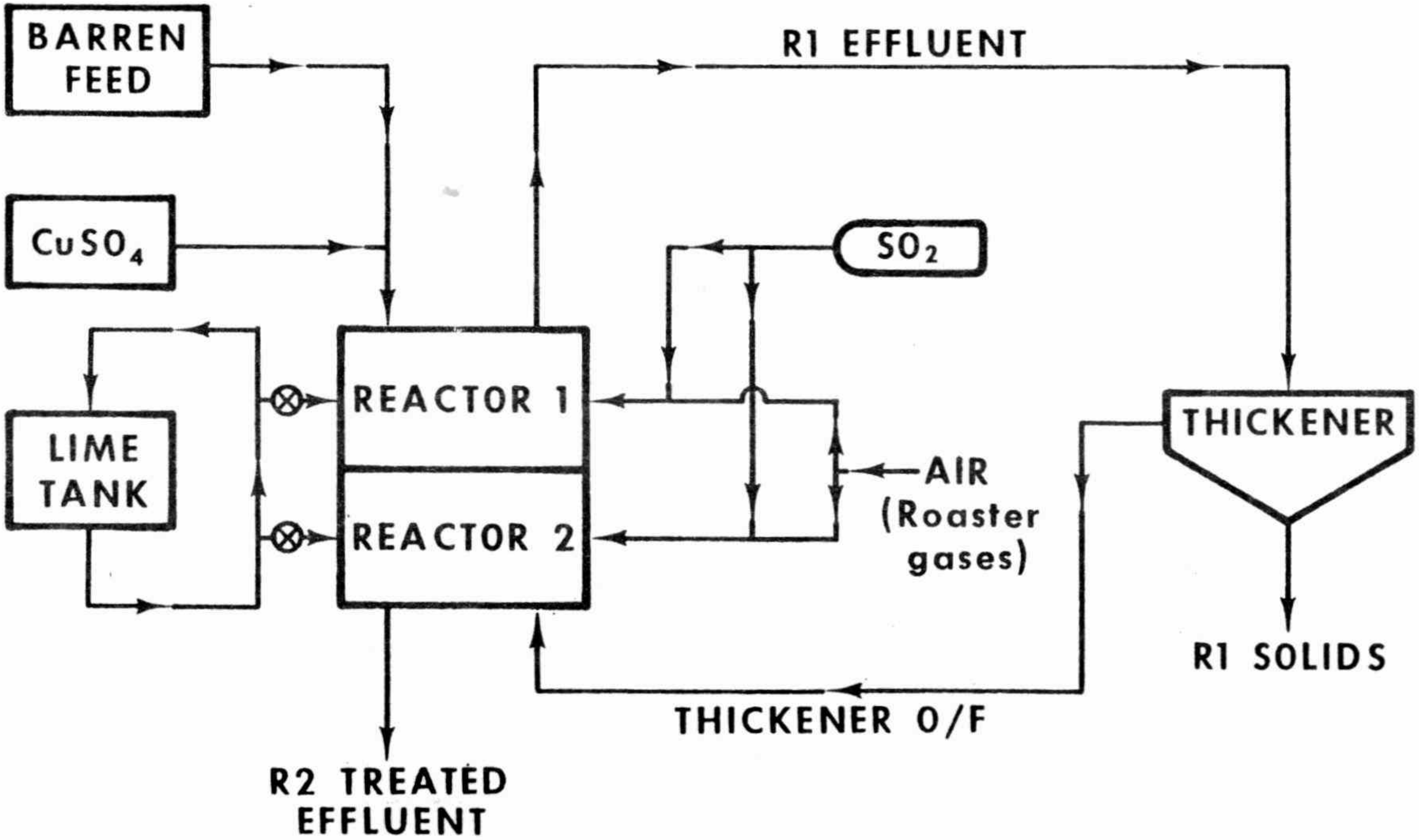
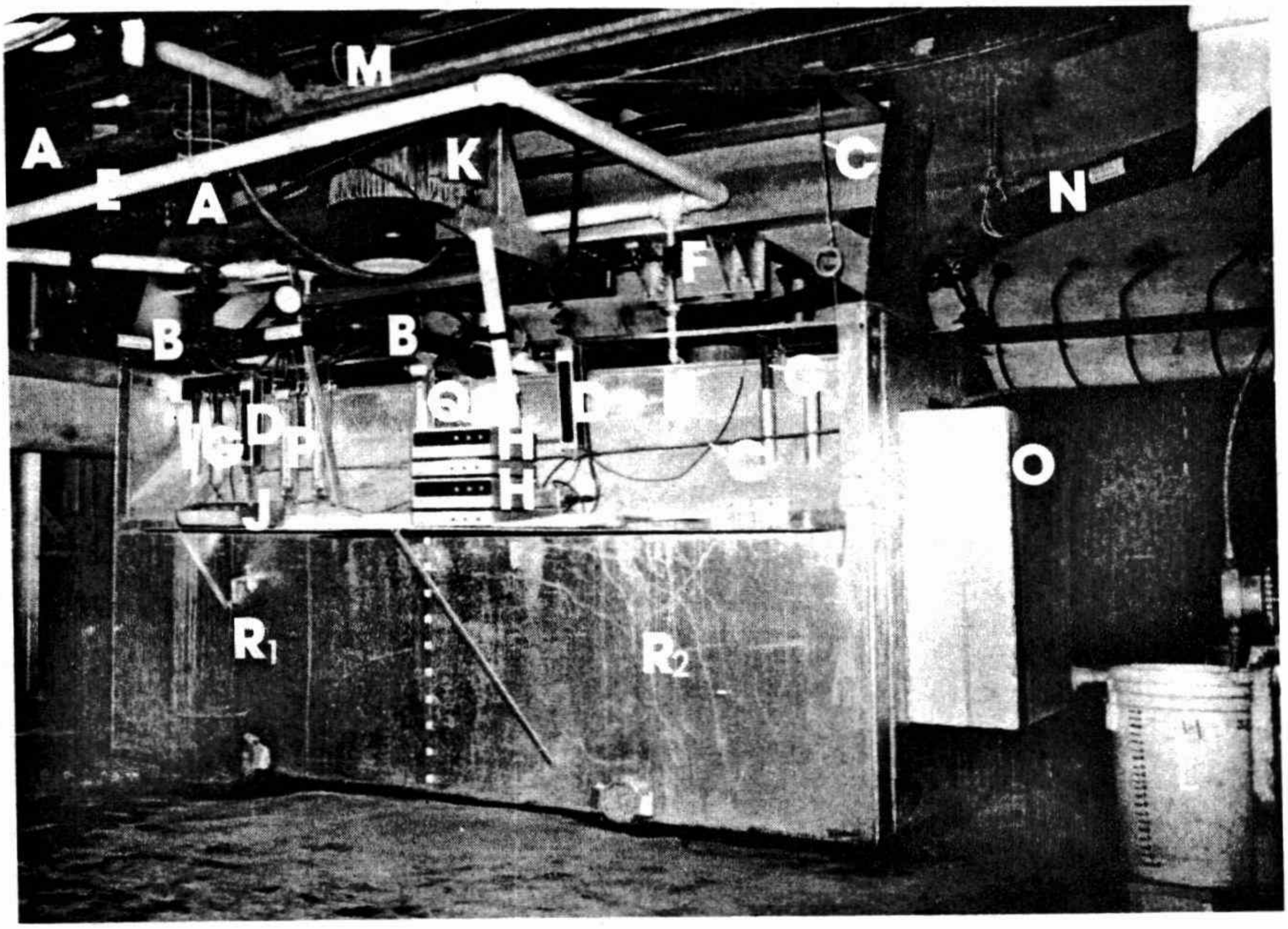


FIGURE 2

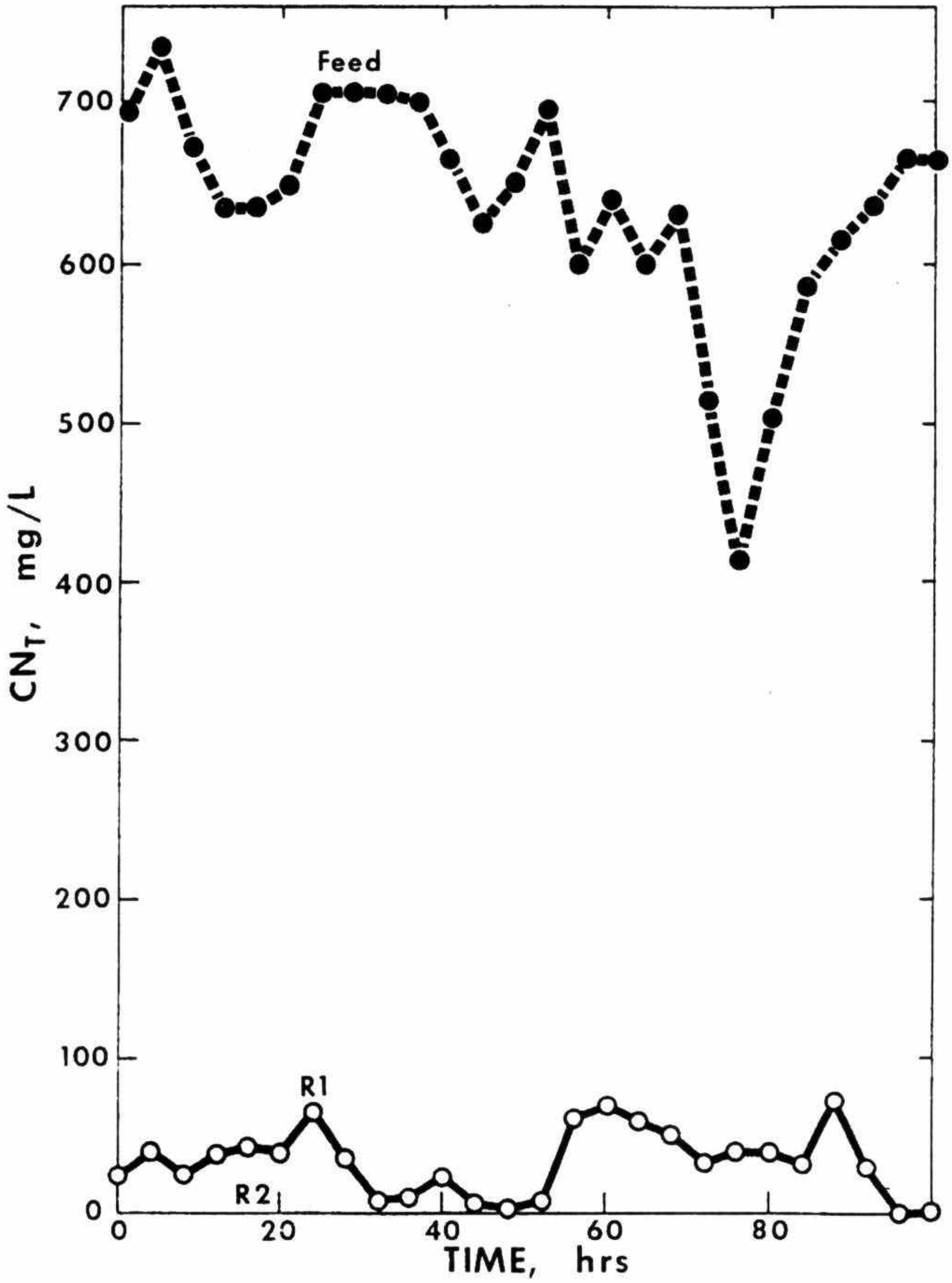
PILOT PLANT FACILITIES AT CAMPBELL RED LAKE



| | |
|---|---|
| A | Feed Barren Liquor |
| B | Air |
| C | Liquid $SO_2$ |
| D | $SO_2$ Flowraters |
| E | Lime Slurry |
| F | Red Jacket Valve |
| G | pH Electrode |
| H | Radiometer Titrator |
| I | Redox Electrode |
| J | Redox Meter |
| K | Motor |
| L | $CuSO_4$ |
| M | Reactor 1 to Thickener |
| N | Thickener O/F to R2 |
| O | Reactor 2 Discharge |
| P | Air Flowrater |
| Q | Exhaust Gases Pressure |
| R1 | Reactor 1 |
| R2 | Reactor 2 |

## FIGURE 3

CYANIDE CONCENTRATION VERSUS TIME
FOR PILOT PLANT



## FIGURE 4

RESIDUAL CYANIDE IN TREATED PILOT PLANT EFFLUENT

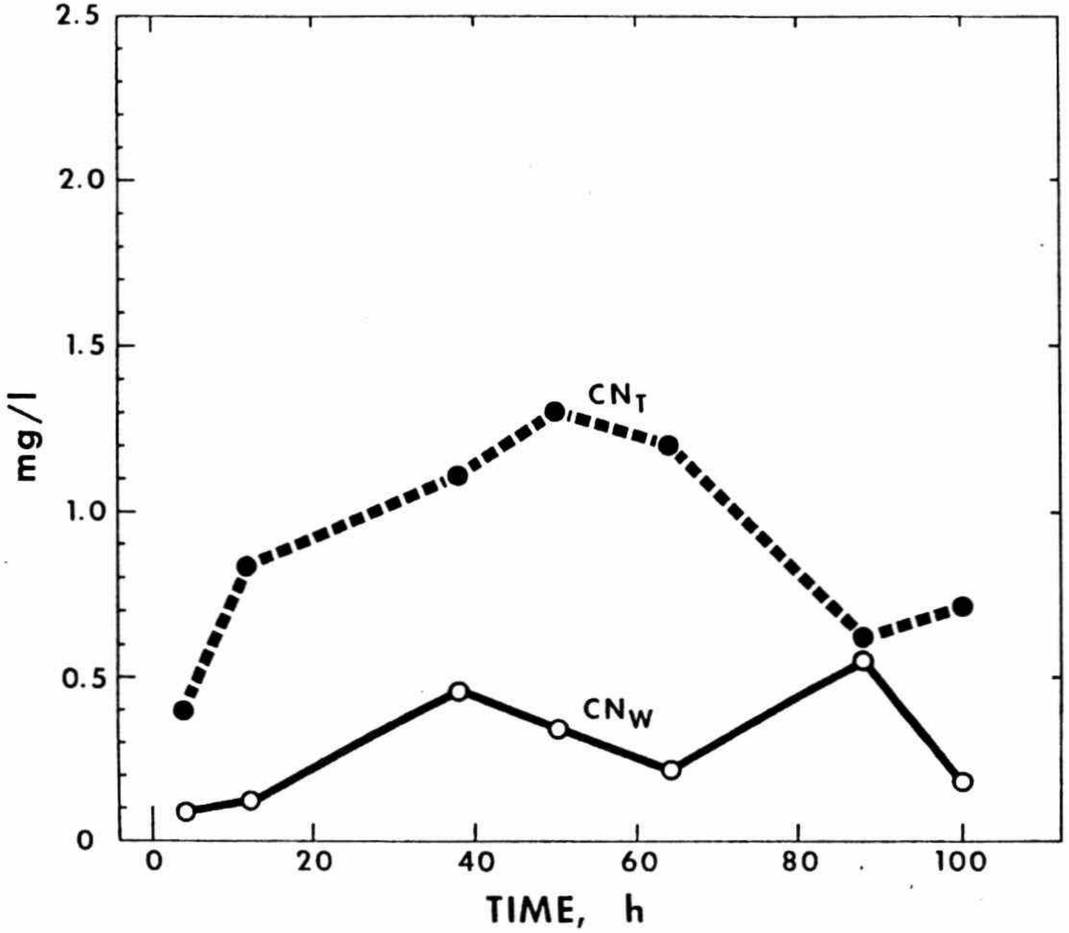
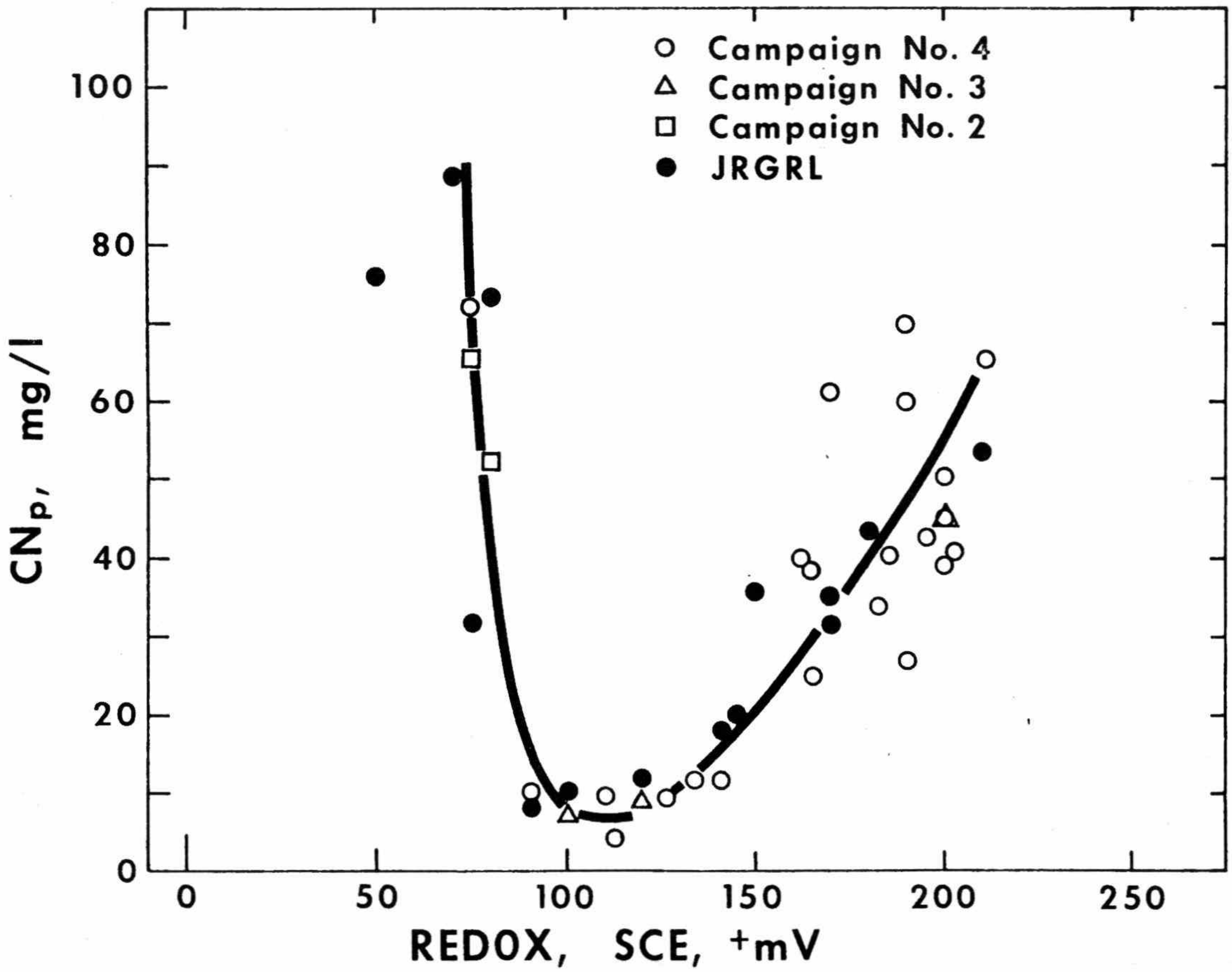


FIGURE 5

CYANIDE IN REACTOR 1 VERSUS REDOX POTENTIAL



# SURVEY OF TRACE SUBSTANCES IN CANADIAN PETROLEUM INDUSTRY EFFLUENTS

by

Mike Heffernan, Chairman
PACE Trace Substance Task Force
c/o Texaco Canada Inc.
Don Mills, Ontario

## INTRODUCTION:

Slide #1 The PACE acronym stands for Petroleum Association for Conservation of the Canadian Environment. PACE is a national, non-profit voluntary association of Canadian oil companies whose main objective is to find and put into place practical controls for environmental problems.

One such problem which is receiving increasing attention from the public and government alike is that of Toxic Substances.

Before I proceed with a discussion of our reports I would like to emphasize that all available information to date indicates that the so called "toxics" are not a problem in refinery effluents.

In my presentation I will outline the background which prompted this study. I will discuss the scope of the program including the sampling and analytical methodology. I will conclude with a summary of the results and an analysis of the findings.

## BACKGROUND

Slide #2 The background begins in the US.. Following the Natural Resources Defence Council consent decree of June 1976, the U.S. EPA published in the Federal Register a list of 65 classes of toxic chemicals for which the agency must promulgate discharge control standards. These chemicals numbering 129 are commonly known as priority pollutants.

Similarly, in Canada the Environmental Contaminants Act was promulgated in 1976 which lists 26 compounds and compound classes as potential candidates for toxics regulation.

In response to the U.S. legislation the API commenced a program to determine the concentration of the 129 P.P. in wastewaters from Petroleum Refineries.

The results of the API study suggested that approximately 35% of the Priority Pollutants were present in refinery effluents. However, most of the pollutants detected are generally found at extremely low levels and are not uniformly present among refineries. Furthermore, pollutants that were detected in samples of feeds to refinery biotreatment systems were significantly reduced, or eliminated within the treatment system.

Slide #3 In 1979 the PACE Water Quality Committee undertook the first of a series of projects to quantify chemical contaminants in petroleum effluents. The project is known as the PACE Survey of Contaminants in Canadian Petroleum Industry Liquid Effluent. The work was contracted to CanTest Ltd. of Vancouver who in turn subcontracted the sampling program to IEC Ltd. Both companies have extensive experience with this type of work.

Slide #4 The objective of the project was to verify the U.S. results and to develop a reliable data base on Canadian Refineries.

The information would be used for preparation of an informed and timely response to any public or government concerns pertaining to toxic chemicals.

The study is based on a 5 year program which is designed to characterize effluents from all downstream sectors of the petroleum industry. Each phase of the program will be developed and undertaken as a separate study, with the previous years data being used to scope the following year's project.

With this type of program structure we hope to be able to revise and update the study as the lists of priorities change and as toxicity data improve and new analytical techniques are developed.

## SAMPLING AND ANALYSIS PROGRAM

Slide #5 In the first phase of the program we selected 6 refineries and 1 Tar Sand Plant for study. The refineries were selected to provide a diversity of processing methods, age and geographic location.

Slide #6 Briefly, the sampling program calls for collection of two 12 hr. composit samples at three points in each of the six refineries. The sample points were Intake, Feed to the Bio Unit and Final Effluent.

Slide #7 Five samples were collected at the Tar Sand plant - Intake Water, Once Through Cooling Water, Mine Drainage, Dyke Drainage and Final Effluent. All samples were preserved as per EPA protocol and shipped air express to CanTest.

Slide #8 Samples were analyzed for 58 compounds. The list was compiled by selecting all compounds identified in the API study to which we added the chemicals on the EPS Catagory 1 list and all contaminants on the IJC list.

Slide #9 The analysis scheme follows very closely that outlined in the EPA Protocols published in the Federal Register December 3, 1979.

The metals are analysed first by an Inductively Coupled Plasma Spectrograph followed by Atomic Absorption.

Standard APHA procedures are employed in the analysis of routine parameters such as Sulfide, Phenol, Oil and Grease, PH, etc.

The key analytical instrument used for the organic analysis is the Finnigan Gas Chromatograph/Mass Spectrometer. This analysis is backed up with routine Gas Chromatography and High Performance Liquid Chromatography for the PNAs.

## QUALITY ASSURANCE

Slide #10 The analytical program included a comprehensive Quality Control routine involving analysis of transportation blanks and spiked effluents to identify external contaminants and determine recovery efficiencies.

Slide #11 Recovery efficiencies were acceptable for all parameters except the Base Neutral Group where the % recovery ranged from 76.5% at high spike concentrations to 40% at low spike levels. Nevertheless these findings are consistant with values reported in the literature.

The data from the study is contained in 24 tables in the PACE Report.

In the final effluent we found 12 metals ranging in concentration from 155 ppm for Boron to 1 ppm for Selenium. We identified 29 Organic Compounds with mean concentrations between 112 and .02 ppb.

All of this information was subjected to statistical analysis using the "T" test for comparing differences in means and the "T" test for paired data.

Slide #12 This analysis identified what we consider to be the most significant compounds. There were 4 metals, a small amount of cyanide and 5 organic compounds.

The conclusion we drew from this study were:

Slide #13

1. First of all that biological treatment removes significant levels of heavy metals and other toxic organic substances. This feature is well illustrated in the before and after chromatogram.
2. That the levels of these so-called Toxic substances in the final treated effluents are generally of a low concentration.
3. The types of compound and their levels vary from refinery to refinery.

Slide #14 PACE in corporation with Environment Canada is now conducting or has planned further studies to more completely and accurately catagorize trace contaminants in refinery effluents.

A second study which has just been completed provides a comprehensive characterization of all significant organic substances in refinery effluent. The purpose of this project was to identify and quantify trace organic compounds which are not on current government lists but were detected in samples analysed in the first study.

The methodology for the project involved:

Collection of one 12 hour composit effluent sample from each of three refineries.

Samples were then put through a GC/MS analytical scheme involving:
1) Target analysis
2) Survey search
3) Confirmation

Slide #15 The project has identified 5 groups of compounds which are considered to be present in "significant" quantities.

The predominant substances included xylenes; substituted benzenes, naphthlenes and phenanthrenes; and substituted phenols.

The effect of biological treatment is evident in that the parameters were found at much lower levels in effluents than in the intermediate treatment waters.

Slide #16 The third project which we call our Variability Study is in the Draft Report stage.

The objective of this study is to determine the variability of concentration of selected compounds at a particular refinery.

A 24 hr composit sample from the intake and effluent were collected once per week for a 15 week period.

These samples were analyzed for the predominant compounds identified in the previous studies.

In order to properly evaluate the variability in concentration which is attributable to the refining operation it was necessary to accurately determine the analytical variability. This was accomplished by incorporating a rigorous QA/QC into the overall analytical scheme. The primary difference between this study and the previous work centers around the use of deuterium labelled compounds.

In this study a number of deuterated chemicals representing many of the compounds under investigation were added to each sample analyzed. These deuterated compounds have different molecular weights than the corresponding authentic compounds and can therefore be separately quantified. In this way quality control data can be generated for each sample analysed.

Slide #17 The recoveries of the purgable compounds was as expected, extremely variable with mean recoveries in the high 80s and standard deviations ranging from 16 to 69%.

The recoveries of the base neutral compounds were lower than the purgables but were less variable with standard deviations of 15 - 34%.

The recovery of acid extractable compound was lower again. The mean recovery of Phenol was 30%.

Slide #18 A preliminary review of the results of this study indicate that the average concentration of compounds in the intake and the effluent appear to be similar for many compounds, which would suggest that the refinery is not contributing numerous organic chemicals to the receiving water.

Slide #19 However some compounds can be directly attributed to refinery operations (Phenol and Pentane) and as this slide indicates, the effluent concentration of the other compounds do on occasion exceed the inlet concentration.

Slide #20 Our fourth project this year is a Study of the Fate & Transformation of Selected Contaminants in a Refinery Treatment System.

The first three programs have confirmed that biological treatment is an effective process for removing trace organic compounds. The objective of this project is to determine where the organics have gone or what has happened to them. Are they stripped off in the areation tank? Are they biologically degraded or are they absorbed on the biomass.

This program involves the collection of 5 consecutive 24 hour composit samples from 8 points within one refinery.

Slide #21 I would like to conclude this presentation with a quote by John Hernandez deputy administrator of the U.S. EPA from his testimony before the Senate environmental subcommittee.

"Contrary to the agency's initial concerns, we have found that well-operated biological treatment systems can effectively control many of the toxic materials of concern,"

"For example, our technical analyses of the petroleum refining industry show that the traditional biological treatment methods required by the regulations for conventional pollutant removal can also reduce organic toxics and phenols by 95%.

Because effluent guidelines for controlling conventional pollutants provide treatment that is also effective in controlling toxic organics and heavy metals, further control measures may be unnecessary for certain industrial discharges."

**Petroleum Association**
**for Conservation of the**
**Canadian Environment**

PACE
APCE

**MEMBER COMPANIES**

BP CANADA INC.
GULF CANADA LIMITED
HUSKY OIL OPERATIONS LTD.
IMPERIAL OIL LIMITED
PETRO-CANADA
PETROSAR LIMITED
SHELL CANADA LIMITED
SUNCOR INC.
SYNCRUDE CANADA LTD.
TEXACO CANADA INC.
ULTRAMAR CANADA INC.

# PRIORITY POLLUTANTS
# SELECTED EXAMPLES

I **PURGABLE ORGANICS** (31)

BENZENE • TOLUENE • ETHYLBENZENE

II **BASE/NEUTRAL EXTRACTABLE ORGANICS** (46)

NAPHTHALENE • DIMETHYL PHTHALATE • ANTHRACENE

III **ACID EXTRACTABLE ORGANICS** (11)

PHENOL • 2-NITROPHENOL • p-CHLORO-m-CRESOL

IV **PESTICIDES/PCB'S** (26)

ALDRIN • HEPTACHLOR • TOXAPHENE

V **METALS & INORGANICS** (15)

ARSENIC • CHROMIUM • CYANIDE

# Survey of Trace Substances in Canadian Petroleum Industry Effluents

A Report for the

Petroleum Association
for Conservation of the
Canadian Environment (PACE)

**can test ltd.**

**International
Environmental
Consultants Ltd.**
Vancouver / Calgary / Toronto / Montreal

**OBJECTIVE:**

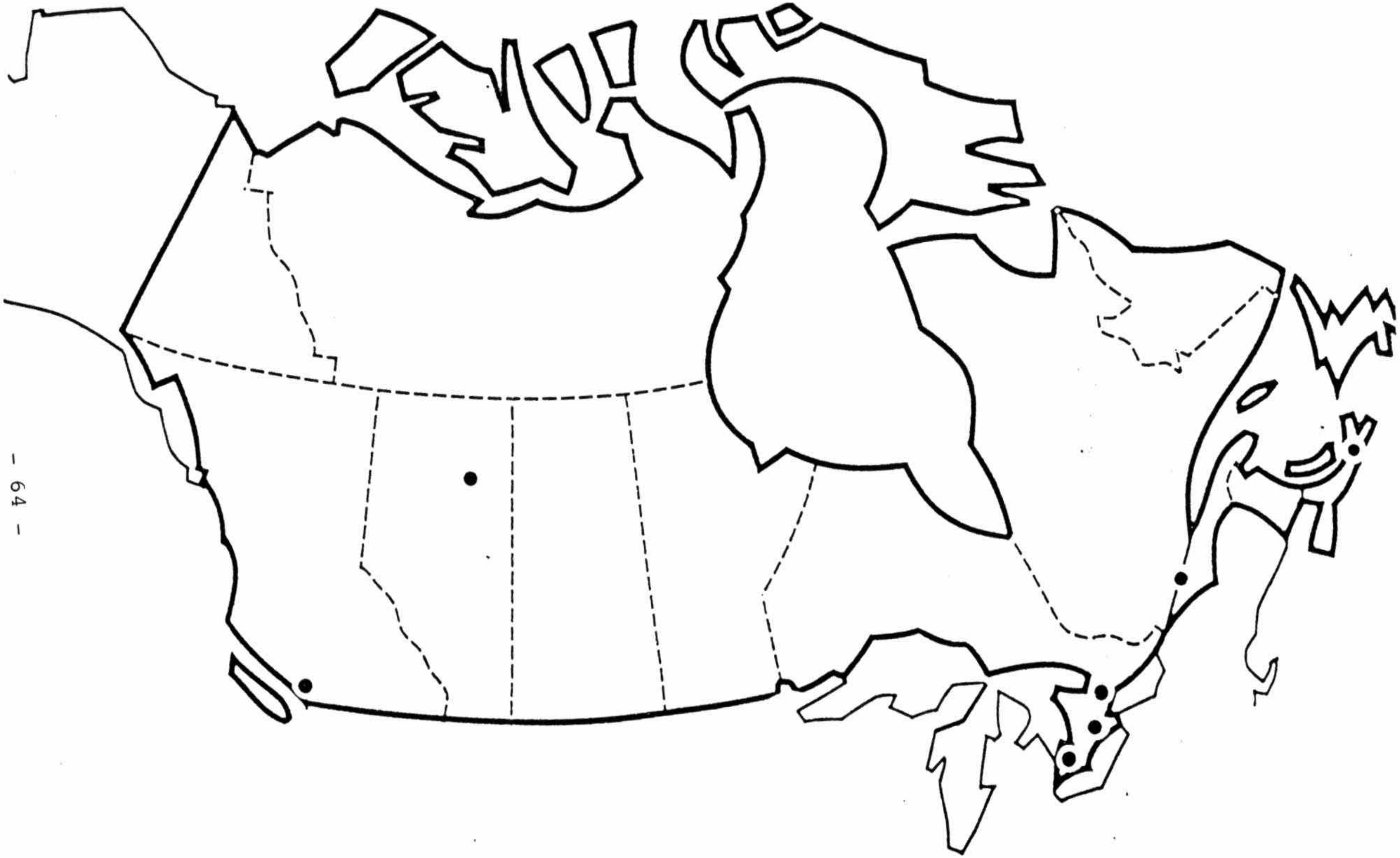
- Develop a Canadian data base on trace contaminants

**PURPOSE:**

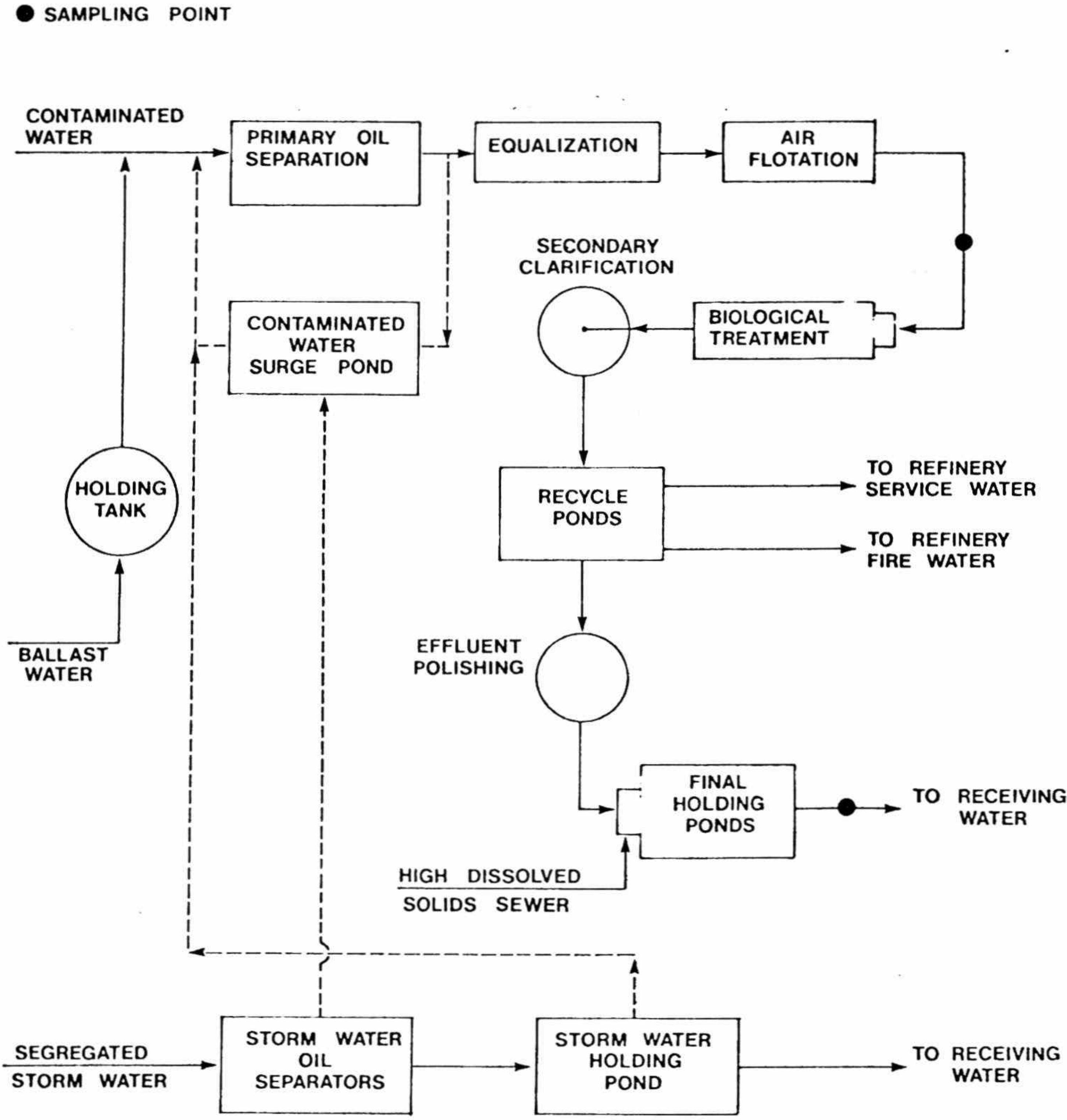
- To provide information for preparation of an informed and timely response to any proposed "Toxic" legislation

**SCOPE:**

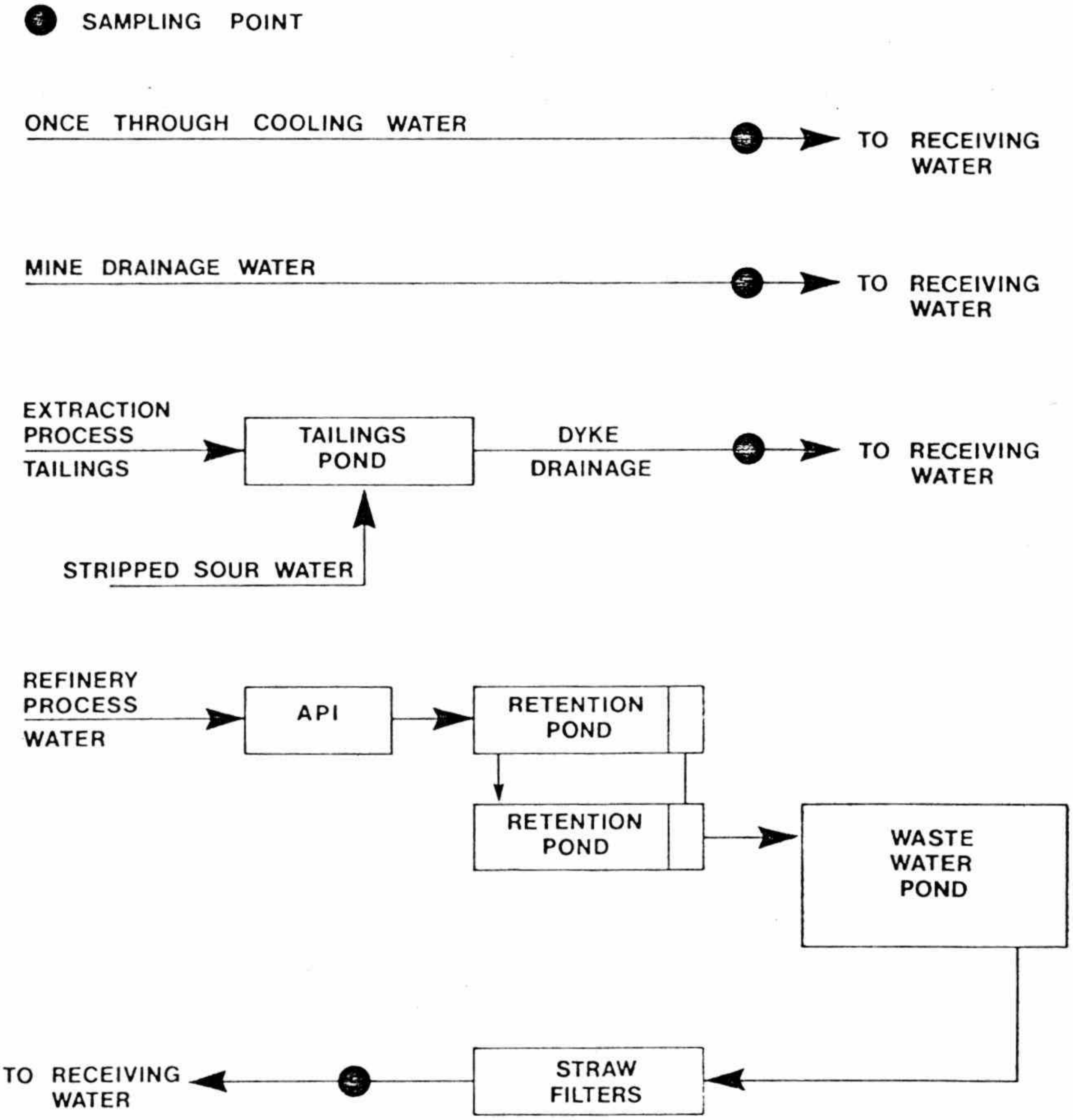
- Five year program
- Characterize effluents from all downstream sectors
- Each phase undertaken as a separate study



# SIMPLIFIED SCHEMATIC FOR WASTEWATER TREATMENT SYSTEM – REFINERY

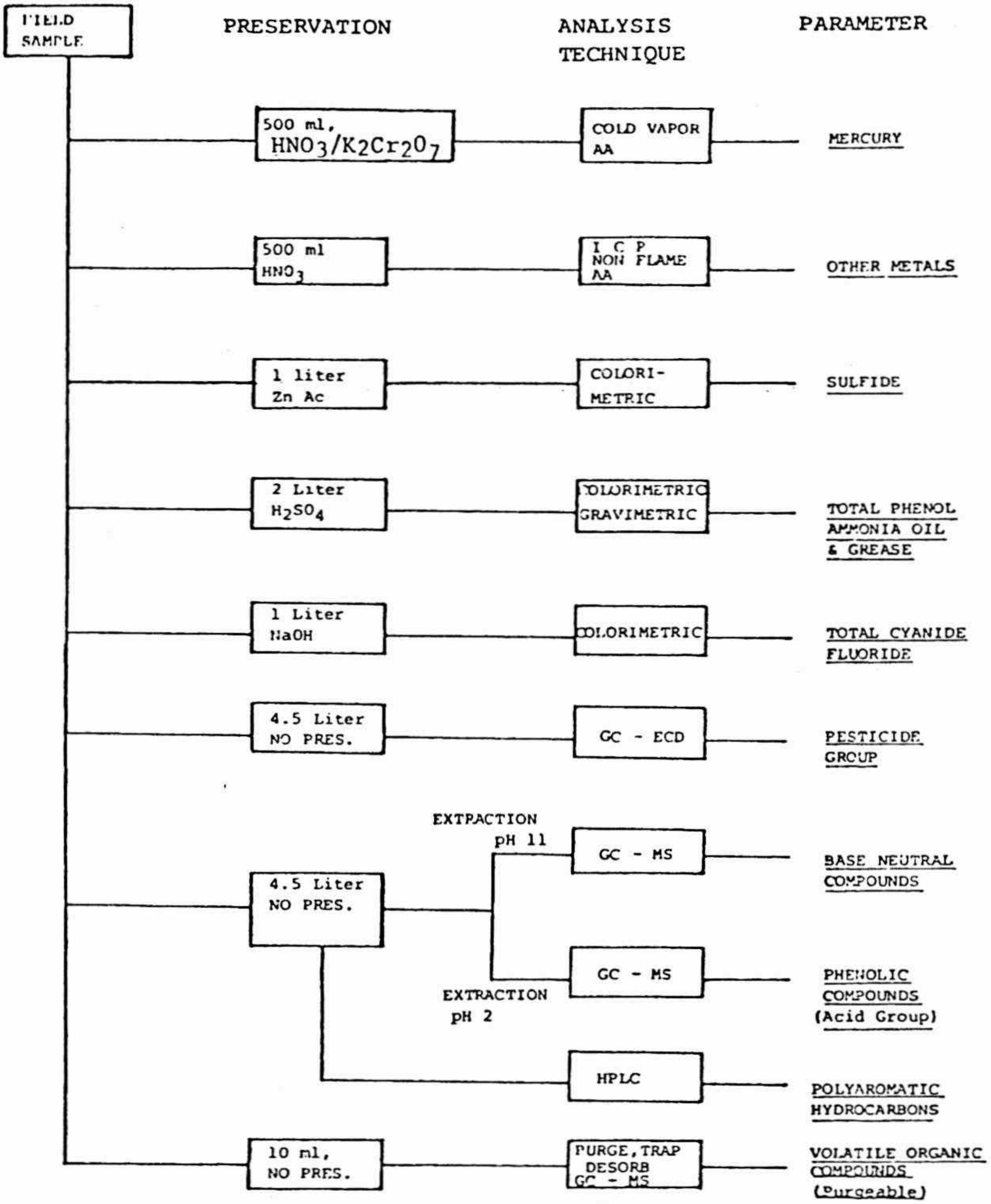


# SIMPLIFIED SCHEMATIC FOR WASTEWATER TREATMENT SYSTEM –



# LIST OF 58 PARAMETERS SELECTED FROM:

- API 1978 Priority Pollutants Study
- EPS Catagory I List
- IJC Guidelines for Control of Toxic Substances in the Great Lakes



Analytical flow diagram showing the field preparation and subsequent analysis of the sample aliquots.

## QUALITY ASSURANCE:

Contamination identified by Transportation blank carried through complete analysis.

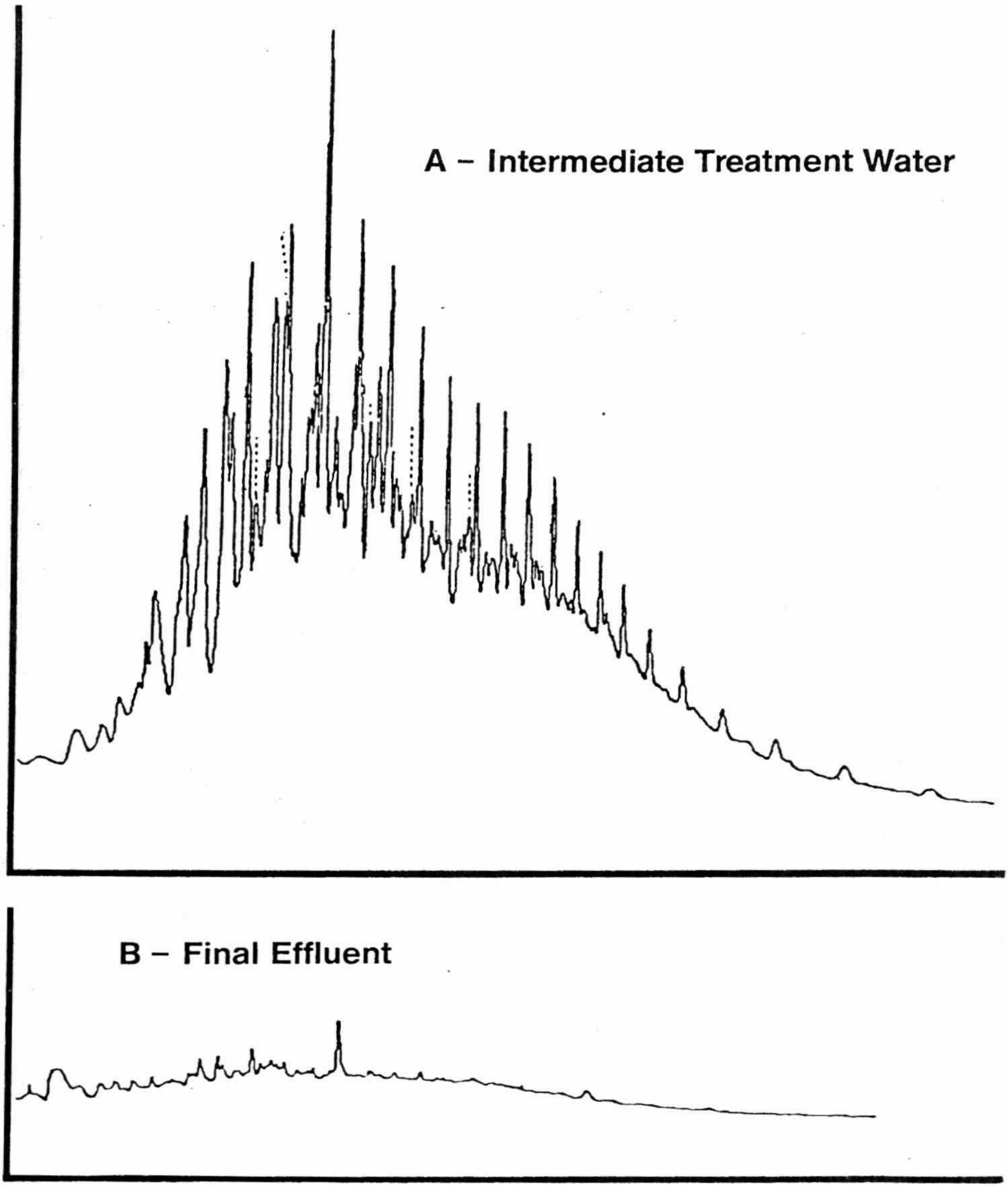
Spiked effluent sample used to determine % recovery.

# QUALITY ASSURANCE DATA

| PARAMETER | LEVEL OF SPIKE | AVERAGE % RECOVERY |
|---|---|---|
| Metals | .004–.068 mg/L | 89.6 |
| Conventional (CN, F, Ammonia Sulphide, Phenol) | 0.1–20 mg/L | 91.1 |
| Purgeable Group | 40 ug/L | 82.2 |
| Base Neutral Group | 66.7 ug/L | 76.5 |
| Base Neutral Group | 3 ug/L | 40 |
| Acid Group | 66.7 ug/L | 83 |
| Pesticide Group | 2 ug/L | 82.4 |

# SUMMARY OF RESULTS

| SUBSTANCE | MEAN CONCENTRATIONS µG/L | | | |
|---|---|---|---|---|
| | INTAKE | INTERMEDIATE TREATMENT | FINAL EFFLUENT | % REDUCTION |
| ARSENIC | 2 | 18 | 6 | 66 |
| CHROMIUM | 14 | 360 | 190 | 47 |
| SELENIUM | 0 | 40 | 7 | 83 |
| NICKEL | 9 | 27 | 15 | 44 |
| CYANIDE | 10 | 130 | 70 | 46 |
| TOLUENE | 3 | 1802 | 208 | 88 |
| BENZENE | 0 | 1706 | 226 | 87 |
| PHENOLS | 9 | 23500 | 2040 | 91 |
| NAPHTHALENE | 0 | 86 | 7 | 92 |
| CHLOROFORM | 0 | 5 | 11 | |



RECONSTRUCTED ION CHROMATOGRAM OF THE BASE NEUTRAL FRACTION FROM REFINERY 6

# SURVEY OF TRACE SUBSTANCES

## (PACE /Environment Canada)

## PART 2

Comprehensive Characterization of Organic Substances in Refinery Wastewaters

| | |
|---|---|
| OBJECTIVE: | Quantify non-specific trace organic compounds observed in Part I |
| METHODOLOGY: | Collect Two 12 Hour Composit Samples from each of 3 Refineries.<br>GC/MS Analysis as follows:<br>a) Target Analysis<br>b) Survey Search<br>c) Confirmation |

| COMPOUNDS | INTERMEDIATE TREATMENT ug/L | FINAL EFFLUENT ug/L |
|---|---|---|
| Xylenes | 400-5,200 | 0-780 |
| Alkyl substituted naphthlenes | 1130-3895 | 0-146 |
| Alkyl substituted benzenes | Not Quantified | Not Quantified |
| Substituted phenanthrenes | 0-130 | 0-15 |
| Alkyl substituted phenols | 1456-27955 | 0-135 |

# PART 3

## Variability of Contaminant Concentrations in Refinery Wastewater

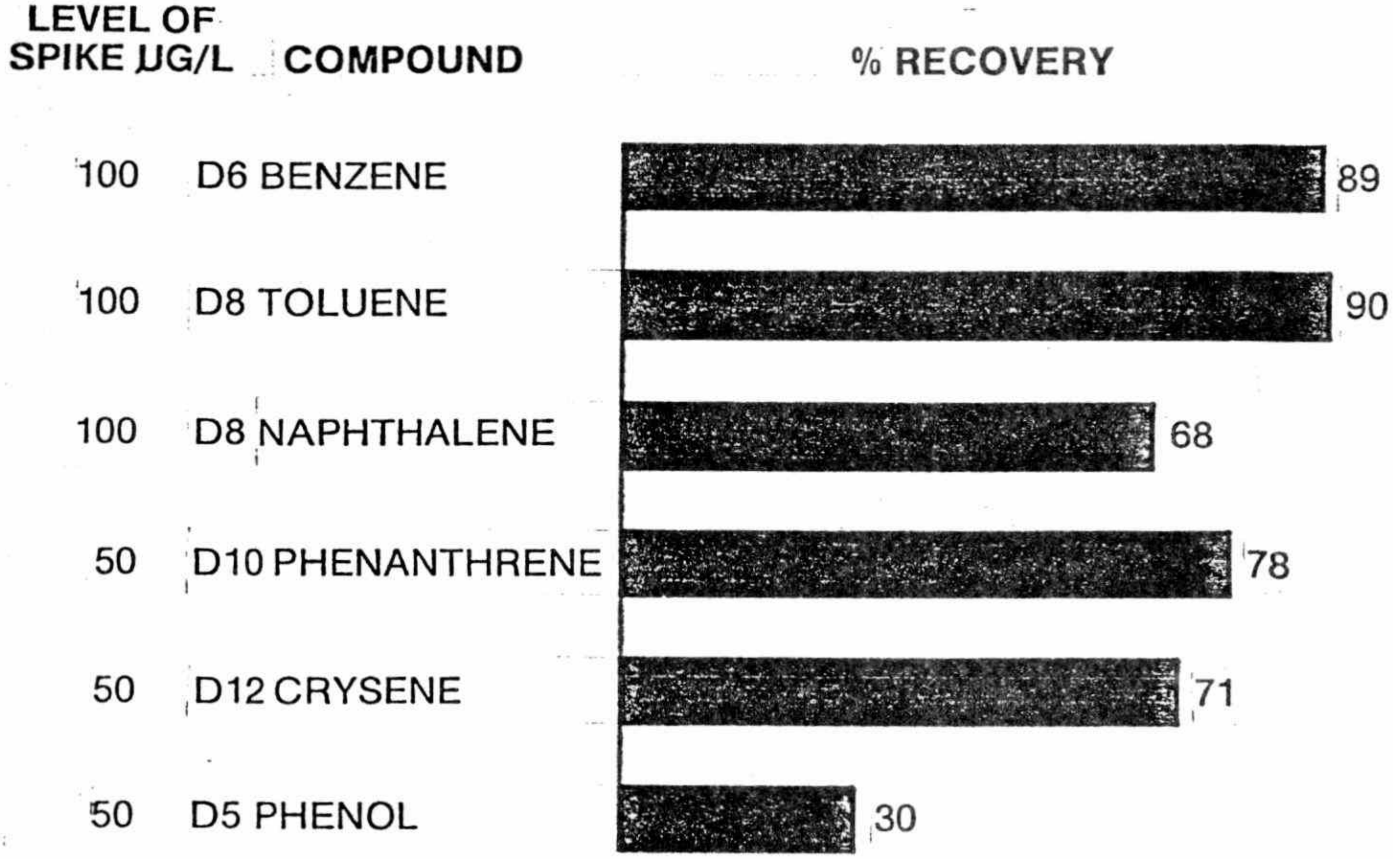
OBJECTIVE – Statistical Evaluation of Process and analytical variability

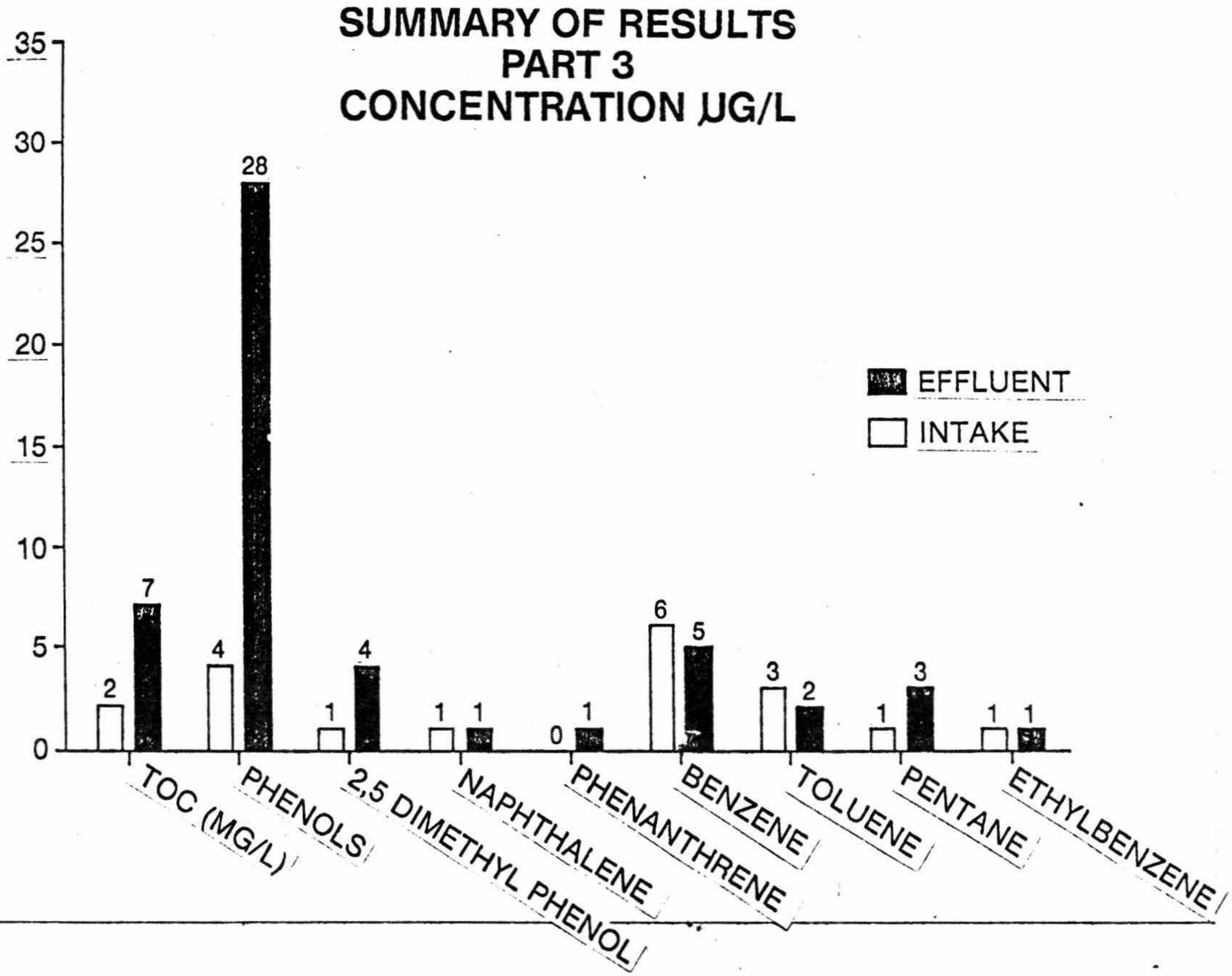
METHODOLOGY – Sample one refinery once per week for 15 weeks

– Analyze for predominant compounds identified in Parts 1 and 2

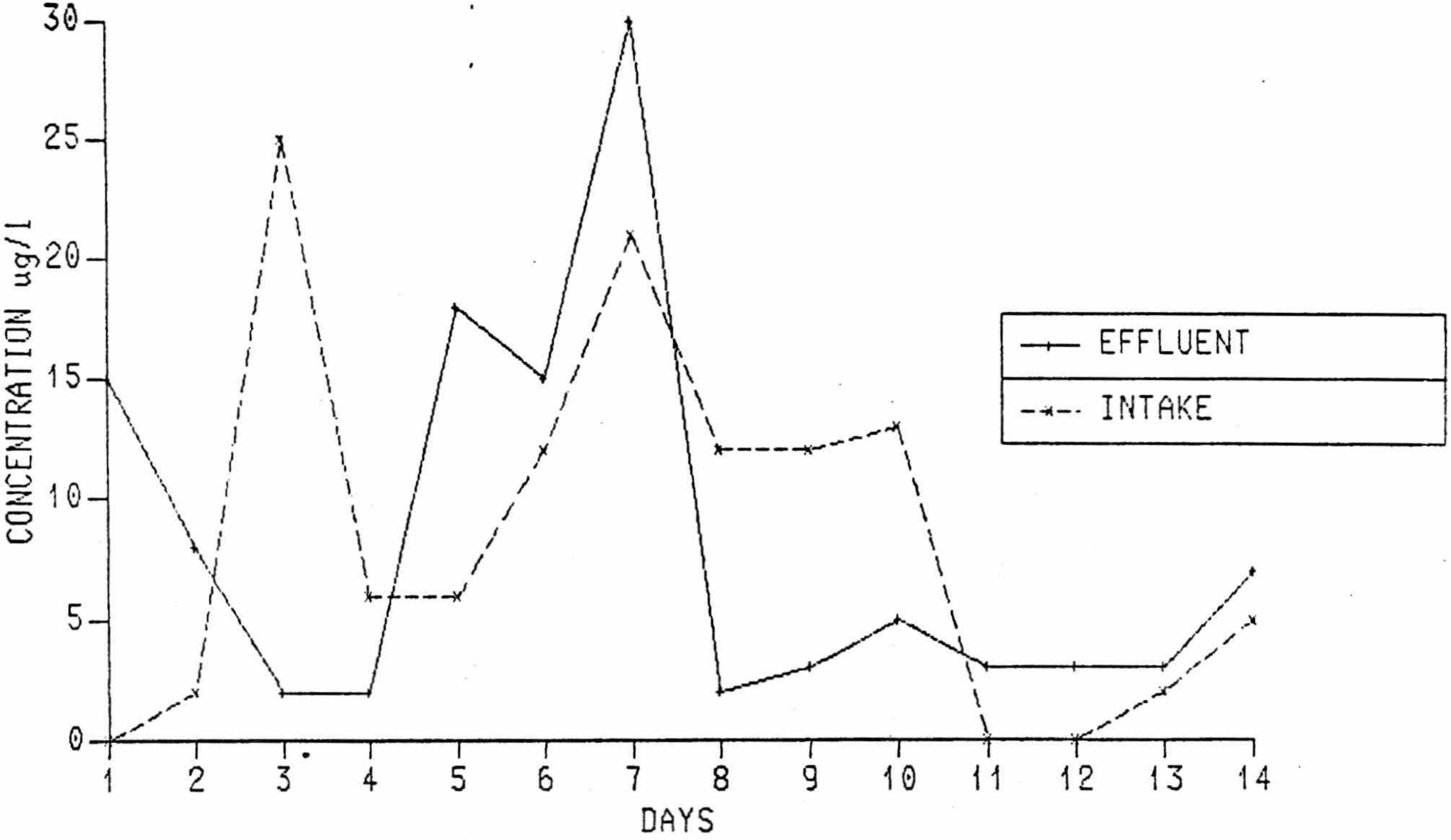
– Expanded QA/QC program

## QUALITY ASSURANCE




SUMMARY OF RESULTS
PART 3
CONCENTRATION JUG/L
35
30
25
20
15
10
5
0
EFFLUENT
INTAKE
2
7
4
28
1
4
1
1
0
1
6
5
3
2
1
3
1
1
TOC (MG/L)
PHENOLS
2,5 DIMETHYL PHENOL
NAPHTHALENE
PHENANTHRENE
BENZENE
TOLUENE
PENTANE
ETHYLBENZENE

## TRACE SUBSTANCE SURVEY
## BENZENE



# PART 4

## Fate & Transformation Study of Selected Contaminants in a Refinery Treatment System

METHODOLOGY – Collect 5 consecutive 24 hour composit samples from each of the following sample points at one refinery:

  - API sludge
  - DAF influent
  - DAF float
  - Air exhaust from DAF
  - Aeration Tank influent
  - Clarifier effluent
  - Clarifier sludge
  - Air over aeration tank

– Analyze for predominant parameters identified in parts 1 & 2

**“CONTRARY TO THE AGENCY’S INITIAL CONCERNS, WE HAVE FOUND THAT WELL-OPERATED BIOLOGICAL TREATMENT SYSTEMS CAN EFFECTIVELY CONTROL MANY OF THE TOXIC MATERIALS OF CONCERN.”**

# *ELECTROCHEMICAL APPROACHES TO POLLUTION CONTROL AND RESOURCE RECYCLING IN THE METAL FINISHING INDUSTRY*

*by*

*Sam Mohanta and Sanka Das Gupta*
*HSA Reactors Limited*
*Rexdale, Ont.*

## Introduction:

The metal finishing industry produces a complex waste water, which is usually extremely toxic. The waste water can contain cyanide complexes of metals such as Cadmium, Copper and Zinc as well as hexavalent Chromium and lead salts. The usual treatment consist of breaking the complexes by Chlorine or hypochlorite and then treating the metals by hydroxide to produce a sludge. This sludge is usually toxic and as can be seen from figure 1 not all the metal species are adequately removed at any given pH. For example the optimum pH for Cadmium removal is 10.7, however at that pH zinc, copper and chromium are appreciably soluble. Thus the conventional chemical method for treating waste waters from metal finishing plants are inadequate to meet strict environmental standards. Moreover the chemical method merely converts water pollution into solid pollution with resultant problems in sludge handling, storage and disposal and the ever possibility of leaching.

## Electrochemical Technology.

Electrochemical treatment of pollution can be an attractive idea, because of its uniquely clean system with both oxidation and reduction reactions can take place via an inert electrode without the need to add chemicals. Using suitable electrodes, a variety of compounds such as cyanide can be oxidised electrochemically, while simultaneously removing metals at the cathode.

Electrochemical treatment of pollution has been postulated for some time however, owing to unsatisfactory reactor design it could not be used to handle large volumes of water efficiently and at a low cost. The development of a carbon fibre reactor(1,2) has made it possible to achieve real time effluent treatment, at low cost.

## Carbon Fibre Reactor.

The Carbon fibre electrochemical reactor radically changes the potential of electrochemical systems for effluent treatment. Most electrochemical processes are limited by mass transfer rates and attempts have been made to develop reactors with improved mass transfer rates, eg. the fluidised bed reactor, the packed bed and other three diamensional particulate reactors. The limitations of these systems mainly stem from enormous non uniform current and potential distribution across the electrodes.

The primary design charecteristics of the carbon fibre reactor is the increase in the mass transfer rates while simultaneously having a controllable and uniform electrode potential over the entire electrode surface. The carbon fibres are produced by the high temperature pyrolysis of precursor materials such as polyacrylonitrile and have very favourable properties as electrode materials because of its hard vitreous surface, electrical conductivity and high hydrogen and oxygen over voltage characteristics. Additionally the fibres have a high modulus, low density, good thermal conductivity, low coefficient of thermal expansion, chemical inertness, good resistance to thermal shock, good frictional characteristics, high vibration damping factor and excellent fatigue resistance.

Another important property of carbon fibres is their large surface area to volume ratio. The fibres are typically $5\mu$ to $15\mu$ in diameter and 1 gram of fibre has a surface area of $2.6X10^6$ $cm^2$. This is about 1000 times larger surface area per unit volume than other types of particulate electrodes. As a result of the increased surface area the mass transfer rates of the carbon fibre reactor approach those achieved by heterogeneous catalytic reactors. The major operational advantages of this reactor are as follows:

- can operate at lower true current densities without corresponding decrease in output.
- low capital cost as the space time yields are high.
- low residence time
- electrochemical processes which to date have not been commercially successful may prove so with this reactor.

## Carbon Fibre Reactor in the Metal Finishing Industry.

The HSA carbon fibre reactor can be utilised in the metal finishing industry for pollution control and resource cycling. Anodic reactions are cyanide oxidation while the cathodic reactions are reductions of metallic species, with subsequent recovery of the metals. Thus the equipment has a finite payback period which is usually two years and can be as low as six months depending on a number of factors such as metal value, water savings and chemicals saved. The advantages of the HSA system include:

- resource recovery as a means to controlling pollution
- the recovered metals do not contain impurities unlike methods such as evaporation, reverse osmosis or ion exchange.
- no sludge is produced.
- compact modular units.
- low operating costs.
- based on familiar electroplating principles.
- no excess plating solution recovered unlike evaporation, reverse osmosis and ion exchange methods.

Figure 2 shows an example of the performance of the HSA carbon fibre system versus conventional electrochemical reactors. The residence time required to remove and recover an input copper solution of 100 ppm can take upto four hours in a conventional reactor. With the carbon fibre system greater recovery is achieved with a residence time of 1.7 seconds. This is couple of orders of magnitude better than conventional systems.

Figure 3 and 4 show one of the way an HSA recovery unit can be hooked up to a plating line. A single unit can be hooked upto a multitude of lines. For example one of the HSA system operating in world sized printed circuit board plant in Dallas, Texas is recovering copper from six different sources.

Figure 5 shows the HSA system for cadmium recovery with simultaneous anodic oxidation of cyanide, operating at a metal finishing plant in Ohio(3). Here the system was recovering 99.6% of cadmium, although any recovery greater than 90% would have assured the plant's compliance with their local regulations. Figure 6 shows the effect of a HSA system for Cadmium cyanide pollution control.

## Other Applications.

The HSA electrochemical system is a powerful tool for pollution control, resource recycling and hydrometallurgy for low grade ores. A plethora of possible applications exist. They include:

- direct gold recovery in gold milling operations.
- cyanide recirculation and recovery in a gold mill.
- copper and other heavy metals recovery and pollution control in the printed circuit industry.
- treatment of effluents from Kraft and other pulp and paper mills.

## Conclusion.

The HSA system has recently been commercialised, and credit goes in a big way to the Province of Ontario for their financial backing of this venture.

Presently over 90% of the systems being manufactured are exported. The HSA system is protected world wide by over 60 patents. We hope this system will play a small part in the fight against pollution and for the conservation of scarce resources.

## Bibliography.

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   Das Gupta, S. and Fleet, B. - Nature,263,1976,122.
   Das Gupta, S. and Fleet, B. - US Patents 4,046,663; 4,046,664; 4108754; 4108755; 4108757

2. Das Gupta, S. and Mohanta, S. - CPAR Report 523, EPS, Dept. of Environment Ottawa, 1979.

3. Roof, E. -"Electrochemical Reactor and Associated In-Plant changes at Varland Metal Services".- 3rd Conf. on Adv. Poll. Cont. for the Metal Finishing Industry - EPA-600/2-81-028, Feb. 1981.

# EFFECT OF pH ON THE CONCENTRATION OF HEAVY METALS IN THE EFFLUENT

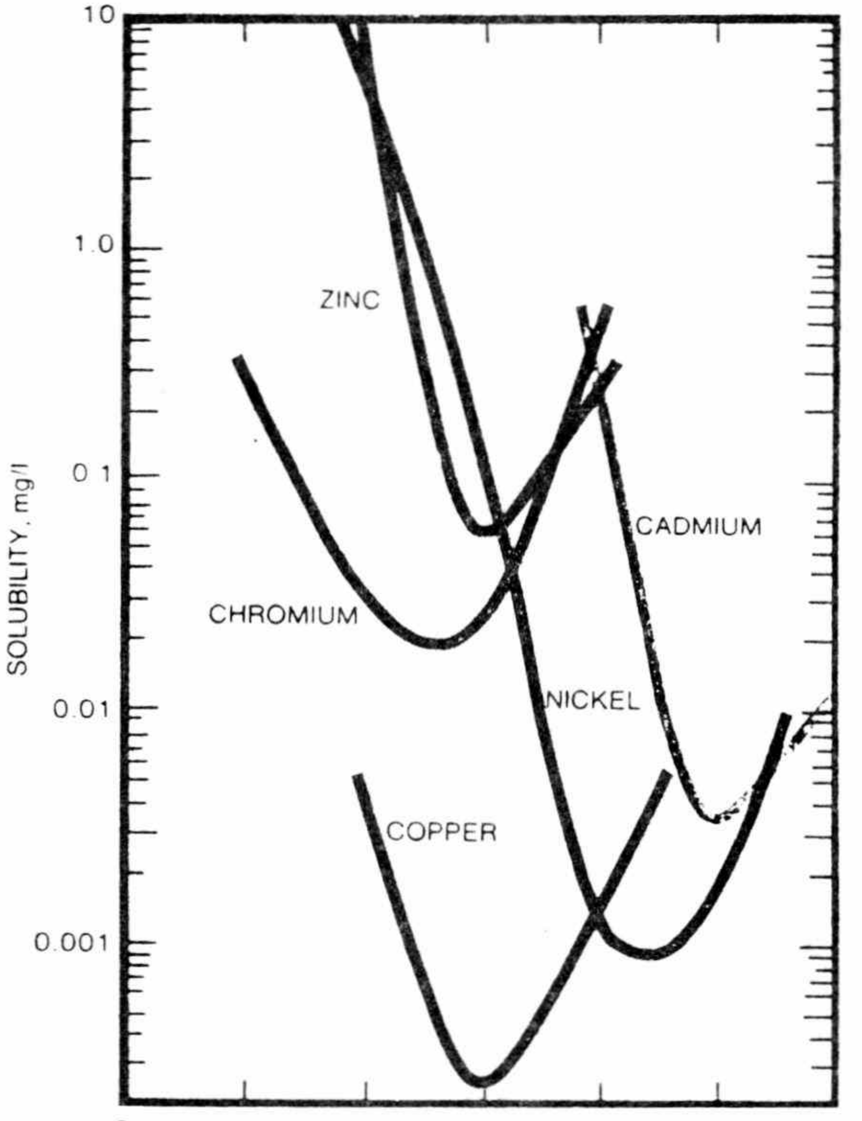
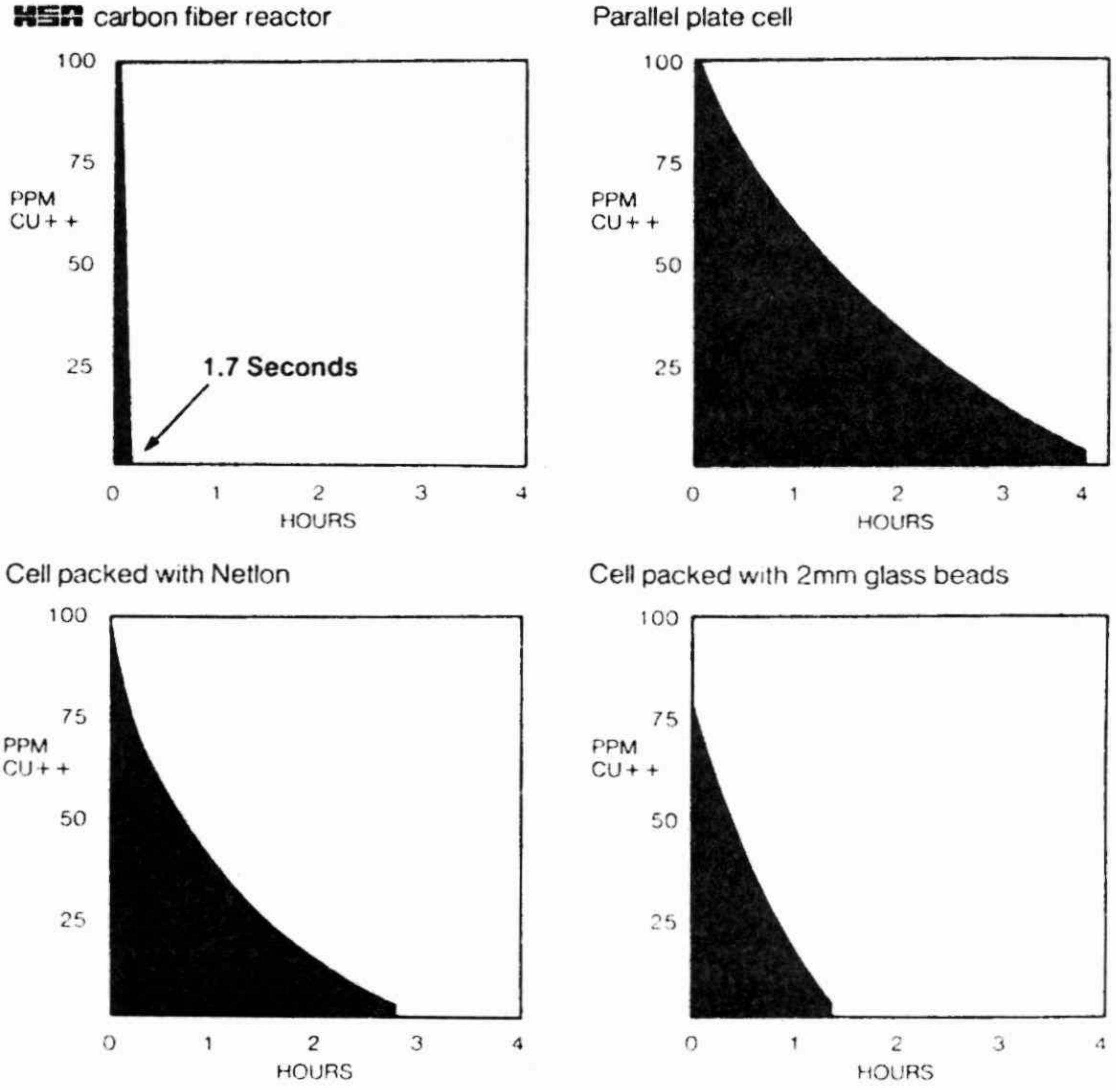


Figure 1


HSA carbon fiber reactor

Parallel plate cell

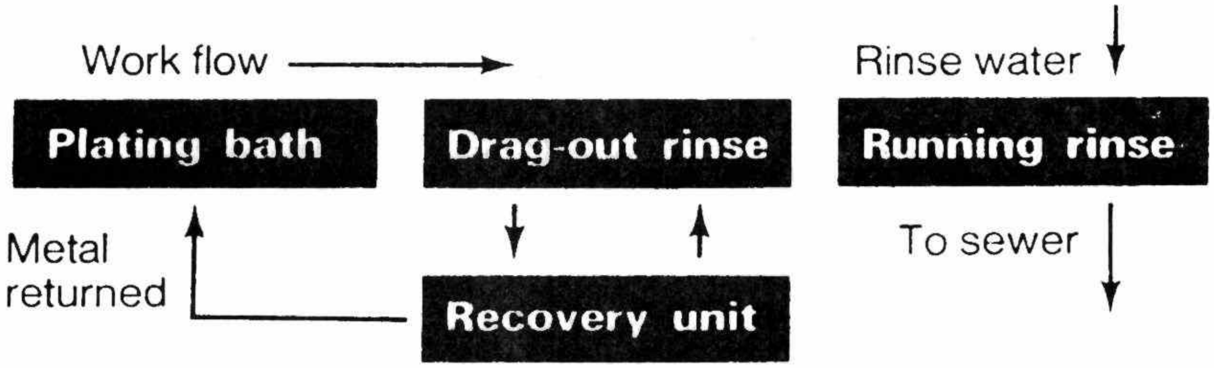
Cell packed with Netlon

Cell packed with 2mm glass beads

Comparison of metal recovery performance — the HSA reactor versus other electrochemical designs

Residence time vs. Metal Removal (Recovery)

Figure 2



**PLATING PROCESS FLOW**

WITH HSA SYSTEM

Note: Multiple sources can be treated by one recovery unit

Figure 3

# PROCESS FLOW DIAGRAM

## HSA METAL RECOVERY SYSTEM

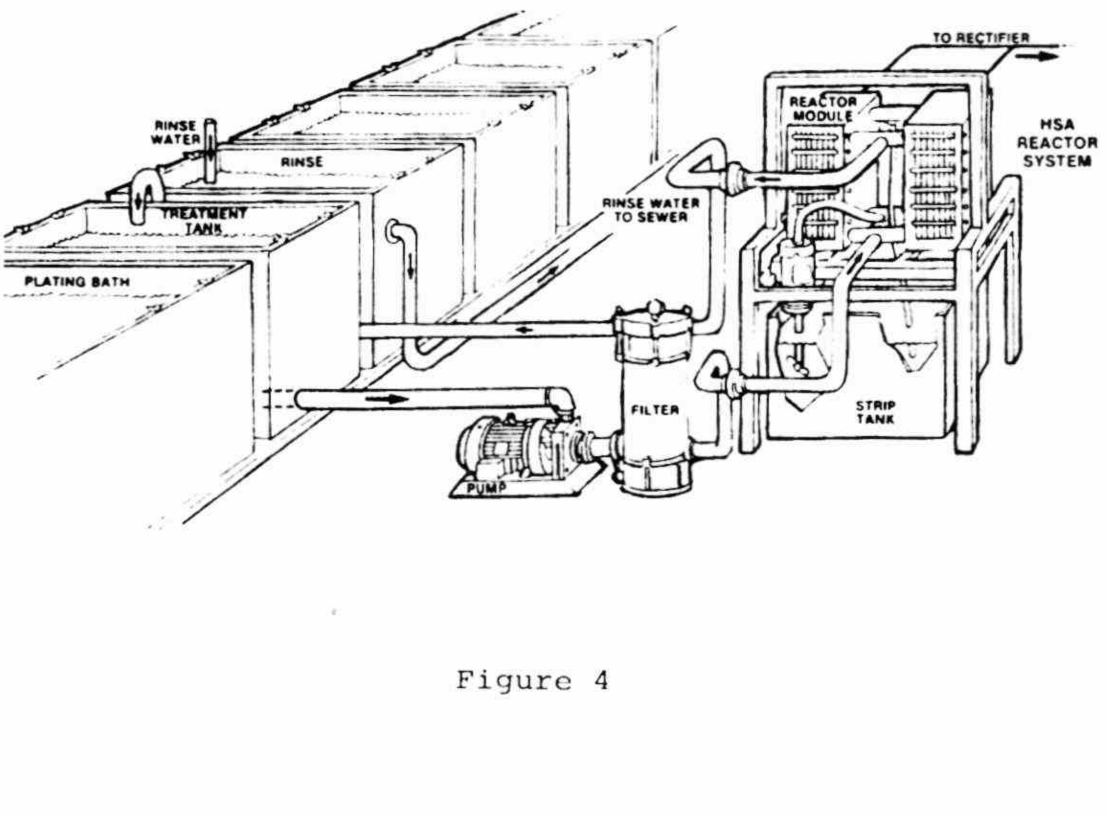


Figure 4

# TYPICAL CADMIUM SYSTEM PERFORMANCE

| | | |
|---|---|---|
| **ASSUME:** | Bath concentration | 15 g/L of Cadmium |
| | Workrate | 8 barrels/hour |
| | Dragout | 3 litres/barrel |

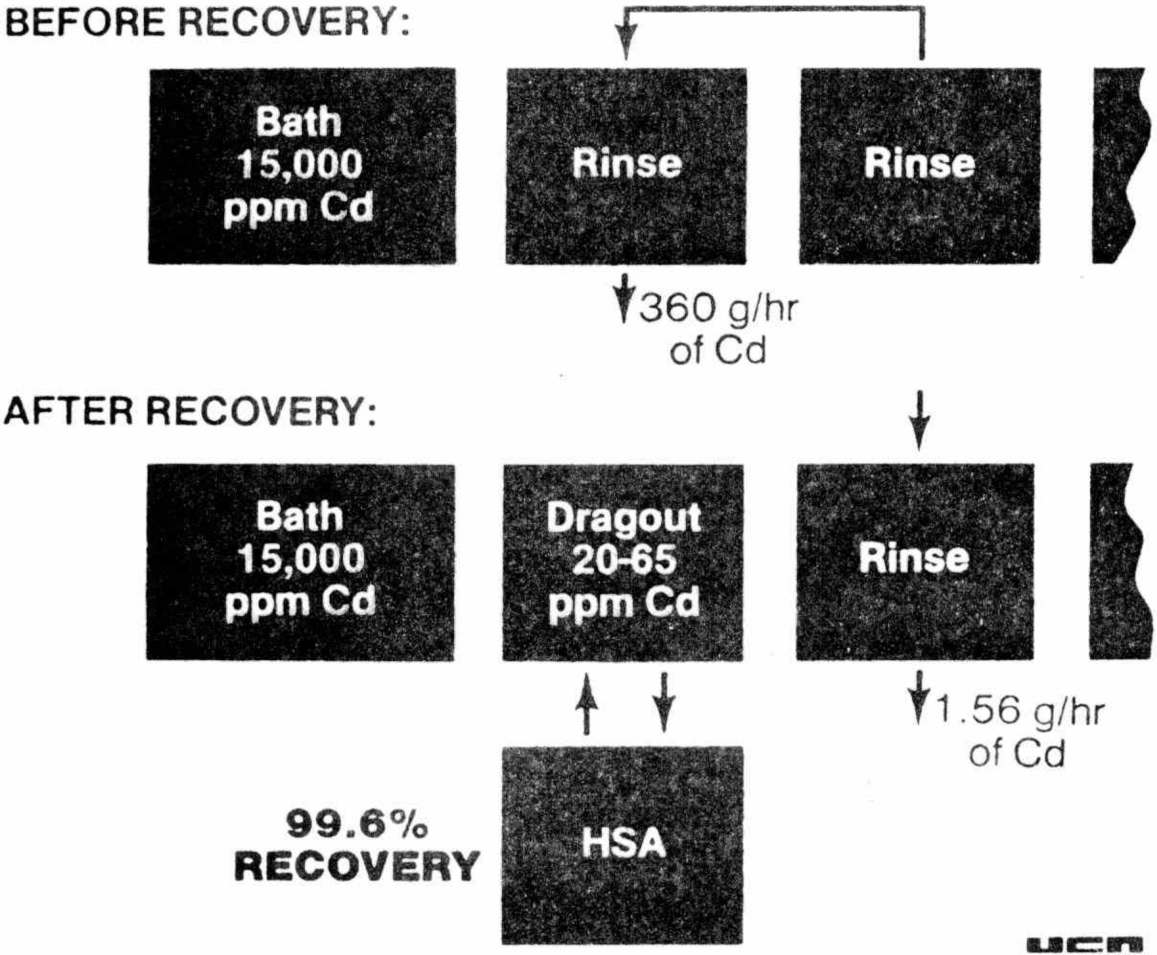
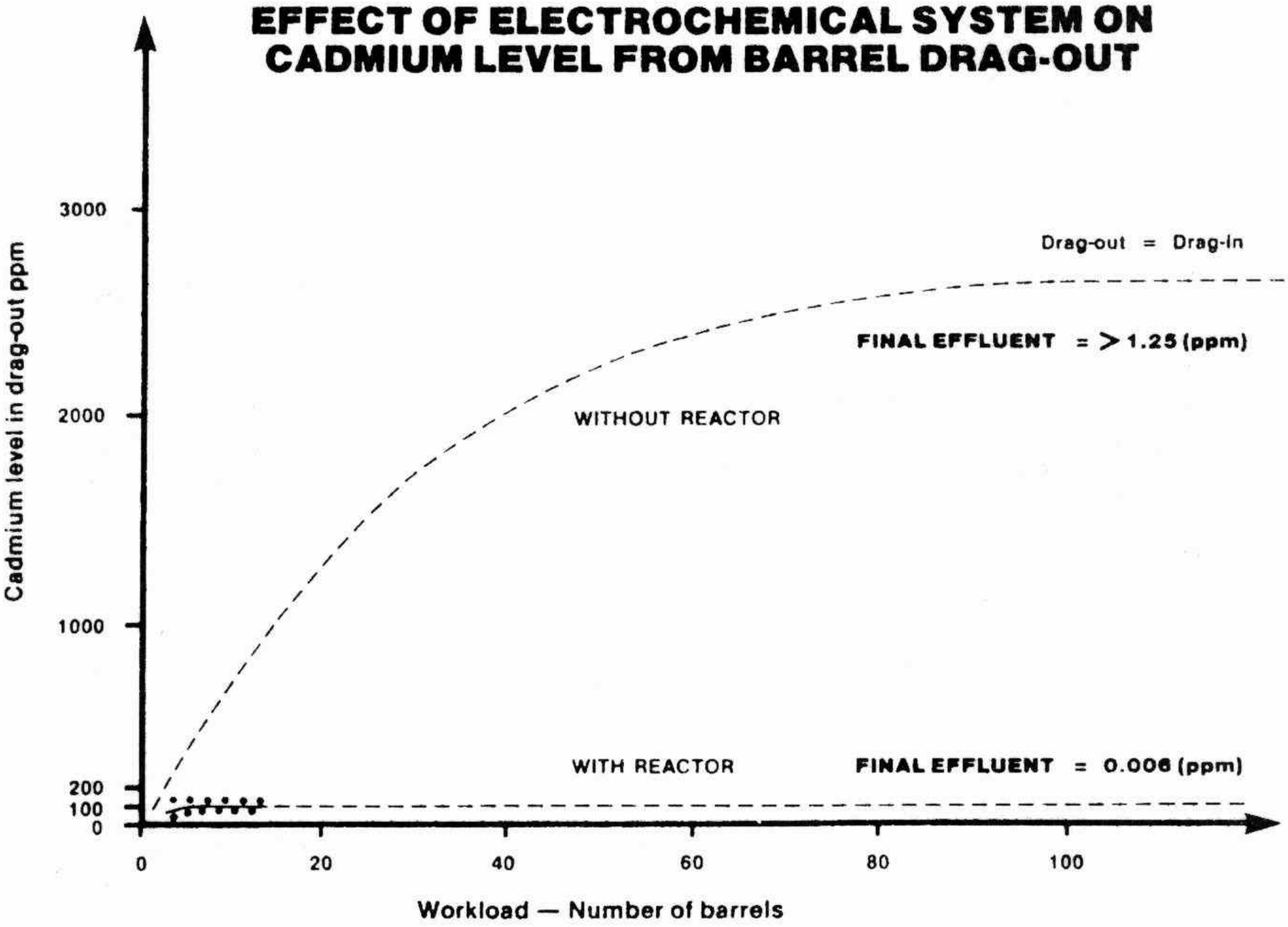


Figure 5



EFFECT OF ELECTROCHEMICAL SYSTEM ON CADMIUM LEVEL FROM BARREL DRAG-OUT

Figure 6

# INDUSTRIAL WASTEWATER TREATMENT PROGRAM AT THE ST. THOMAS AUTOMOTIVE ASSEMBLY PLANT

Brian Wheeler
Project Manager
MacLaren Engineers
Planners and Scientists Inc.
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and

Dale P. Spersrud
Facility Environmental Control Engineer
Plant Engineering Office
Manufacturing Staff
Ford Motor Company of Canada
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## GENERAL BACKGROUND

Ford Motor Company of Canada Ltd. has been operating since 1904, starting in Windsor. There are currently five plant locations in Canada:

- Niagara Glass Plant
- Oakville Assembly and Ontario Truck Assembly Plants
- Windsor Engine and Casting Plants
- Essex Engine and Casting Plants
- St. Thomas Assembly Plant

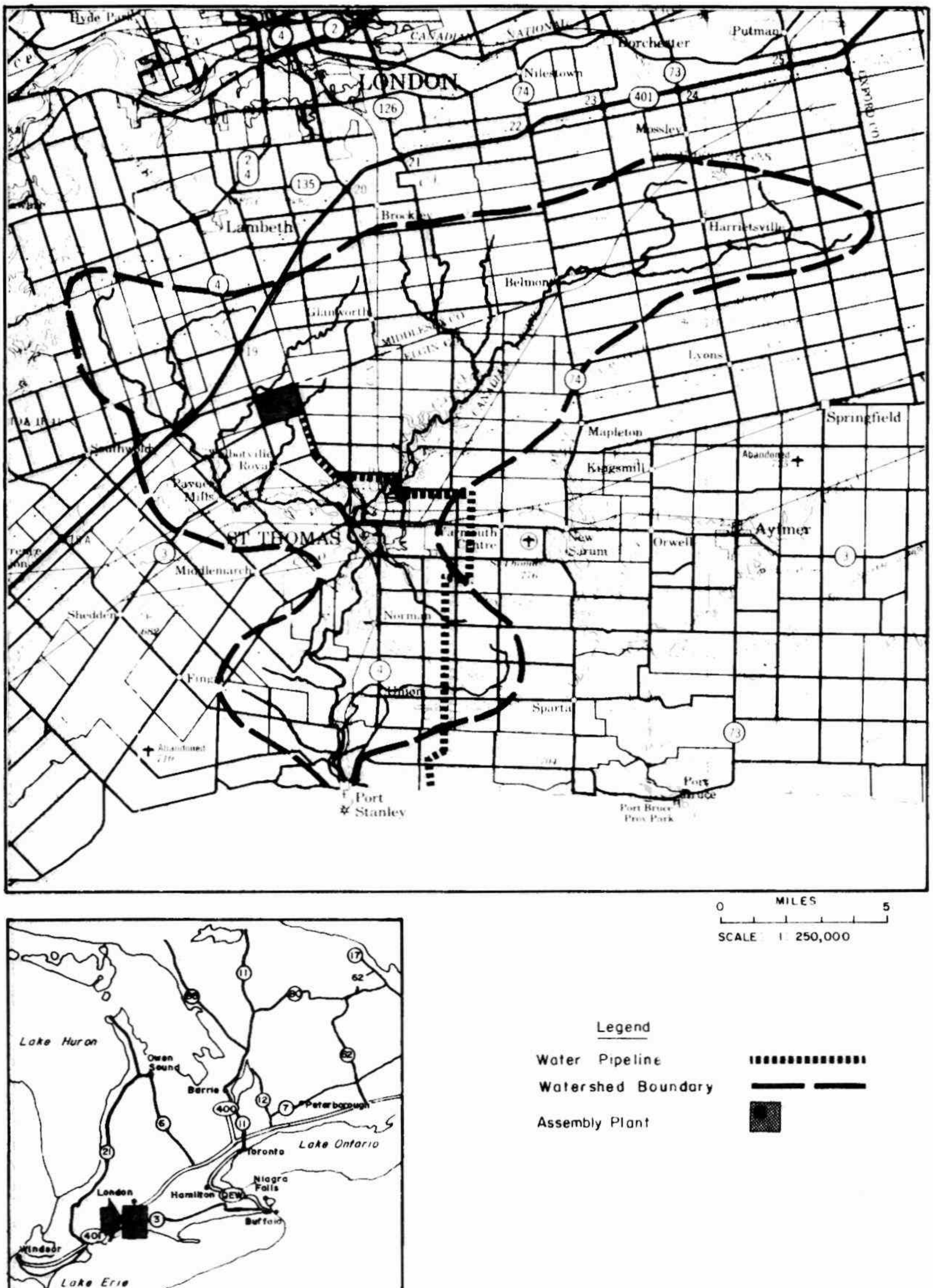
The Company employs some 17,500 persons in Canada, depending upon production schedules, and all manufacturing operations are centered in Ontario. The St. Thomas Plant was constructed in 1965 with production beginning in the winter of 1967. The site (shown in Photograph 1) covers about 623 acres with 42.9 acres under roof and 59.3 acres of pavement. The production capacity is about 60 units per hour with annual production over the past seven years averaging about 163,000 vehicles per year. Peak production was 226,000 vehicles in 1979.

The car lines which have been assembled since the plant started have included the Falcon, Maverick, Pinto, Fairmont/Zephyr, Pinto/Bobcat, and currently, the Exp/LN-7 and Escort/Lynx. The plant presently employs about 3400; however, in higher production periods it has reached 4000.

## REGIONAL SETTING

As shown in Figure 1, the St. Thomas Assembly Plant is located in Elgin County between London and St. Thomas. Thus the site is near major population centers and support industries. The plant is connected by spur to major east-west rail lines through both London and St. Thomas. Highway 401 lies one mile north of the plant via Highway 4.

The water demand of up to 1.5 million Imperial gallons per day is supplied from Lake Erie, some 12 miles to the south, via the Ministry of Environment's (MOE) Lake Erie Water Supply System. The treated wastewaters are discharged to a tributary to Kettle Creek. The catchment of the tributary upstream of the plant is about 10 square miles. Consequently, natural flow in the stream is at or near zero much of the summer and the stream is sensitive to the discharge of treated wastewater.



REGIONAL SETTING

FIG 1

## DESCRIPTION OF MANUFACTURING PROCESSES

The Ford St. Thomas Assembly plant receives body stampings, subassemblies, and individual parts as raw stock. The manufacturing activity consists of:

- **Welding:** The body sheet metal stampings are welded into an unpainted vehicle.
- **Phosphating:** The unpainted vehicle is directed into the seven stage phosphating machine process where, in the first three stages, dirt, oil, metal particles and other unwanted materials are cleaned and rinsed off the sheet metal. The fourth and fifth stages involve subjecting the sheet metal to a zinc phosphate etch and rinse. This process conditions the sheet metal with "microscopic hooks" which provide a close bond between the sheet metal and the prime paint coating and provides a corrosion resistant surface.

  After phosphating, the sheet metal is subjected to a chromic acid solution rinse and deionized water rinse which protects the sheet metal from oxidation until the primer paint is applied.

- **Electrocoat Painting:** The vehicle is immersed in electrocoat prime paint where lead chromate water-based black primer paint is electrically "plated" over the entire vehicle. After two closed recirculated rinses, residual electrocoat paint is rinsed from the vehicle. (This process is shown in Photograph 2.) Electrocoating provides corrosion protection for the car and the rinses from this process are responsible for a significant portion of the Biochemical Oxygen Demand (BOD) in the industrial wastewater generated at this location. In order to minimize the loss of paint from tank dragout, an initial counterflow rinsing system removes the excess paint solids from the vehicle with all of this drainage returned to the paint tank as part of a closed rinse system. This rinsing is done with the permeate generated by passing paint through an ultrafilter which "splits" the paint solids from the liquid phase of the paint.

  The deionized water used for final rinsing, however, is discharged to the process sewer and contains paint solids and solvent with a BOD of about 1000 milligrams per litre. Another source of BOD from this process is the daily bleed-off of 2500 Imperial gallons of permeate which maintains the proper conductivity of the electrocoat paint. This permeate, while mostly water, has a BOD of about 35,000 milligrams per litre caused by dissolved solvents. The electrocoat paint is cured in a direct gas-fired convection oven.

- **Guidecoat Painting and Sanding:** Subsequent to prime electrocoat painting, a solvent-based "guide" primer paint layer is sprayed on the vehicle exterior, baked, and then dry-sanded to insure a smooth painted surface.

- **Topcoat Painting:** The sanded vehicle is wiped clean and directed into the final enamel paint spray booth and subsequent baking oven. "Overspray" from Guidecoat and Topcoat painting operations is collected in water wash backsections. The water for these backsections is recirculated, but is periodically drained to the process sewer.

- **Final Assembly**
  After the paint operation, the vehicle receives the shock absorbers, engine, transmission, etc. From there it is routed to the trim line where vinyl roofs, door locks, body wiring, head liner, weather strip, exterior molding, side glass, instrument panel, trim panel, windshield, etc., are added. Subsequently, tires, batteries, seats, bumpers and hoods are installed and gasoline, oils and anti-freeze are added. Next, functional checks are performed on the power steering, air conditioning, lights, engine and transmission, etc.

  The completed car is then directed to the car wash, leak test, and related adjustment and quality control tests.

- **Additional Wastewater Processes**
  In addition to the basic assembly process, several supporting processes are operated. These involve periodic paint stripping of hooks, chains, carriers, gratings, etc; regeneration of deionizers; cleanup of paint spray booths; backwash and cleaning of ultrafiltration equipment; cleanup of phosphate machine; mop cart dumps from floor cleaning; and spillage and leakage from the final line and various hydraulic systems.

Typical water consumption in the plant is illustrated in Table I. As shown, about one half the total use is for welding gun cooling, a once-through, non-contaminating usage. This wastewater is segregated and bypasses treatment facilities. Sanitary waste water (amounting to about 13 Imperial gallons per capita per day) is also segregated from industrial wastewater for separate treatment. The sources of contaminated industrial wastewater are identified and characterized in Table 2.

TABLE 1

TYPICAL WATER

CONSUMPTION

| Process | Water (Imperial Gallons Per Day) |
|---|---|
| Welding Gun Cooling (summer) | 460,000 |
| Deionized Water | 160,000 |
| Phosphate Machine | 140,000 |
| Electrocoat Rinse | 20,000 |
| Spray Booth Evaporation | 25,000 |
| Water Leak Test | 30,000 |
| Car Wash | 15,000 |
| Sanitary | 45,000 |
| Paint Sludge Pits | 25,000 |
| Tank Dumps (Phosphate & Spray Booths) | 50,000 |
| Miscellaneous | 5,000 |
| Total | 975,000 |

Above is based on a normal two (2) shift production schedule.

### TABLE 2

### CHARACTERIZATION OF SOURCES OF AUTOMOTIVE ASSEMBLY PLANT WASTEWATER

| | FLOW RANGE IMPERIAL GAL/DAY | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Wastewater Sources | 0-10,000 | 10,000 to 50,000 | Over 50,000 | Zinc | Chrome | Lead | Oil | High/ Low pH | BOD/COD | Color |
| Phosphating | | | X | X | X | X | X | X | | |
| Electrocoat Painting | | | X | X | X | X | | | X | X |
| Paint Spray Booths | | X | | X | X | X | | X | X | X |
| Leak Test | | X | | | | | X | | | |
| Car Wash | | X | | | | | X | | | |
| Paint Stripping | X | | | X | X | X | | X | X | X |
| Regeneration Deionizers | | X | | | | | | X | | |
| Ultrafilter Cleaning | X | | | X | X | X | | X | X | X |
| Mop Cart Dumps | X | | | | | | X | | | |
| Final Line Spillage | X | | | | | | X | | X | |
| Hydraulic Leakage | X | | | | | | X | | X | |

## ORIGINAL TREATMENT FACILITIES

The St. Thomas plant's original 1965 construction program included segregated treatment facilities for contaminated wastewaters of sanitary and industrial origin.

Industrial wastes drain by gravity to the wastewater treatment building where they are pumped to one of three 60,000 Imperial gallon batch treatment tanks.

Coagulation and flocculation are performed using ferric chloride, and polymer. Sulfuric acid and caustic soda are available for pH adjustment. After chemical treatment, the wastewater is discharged into two settling lagoons, sized at 1.0 million Imperial gallons each. Clarified supernatent is discharged from the ends of the lagoons and periodically the sludge is removed from these lagoons and directed to sludge storage pits.

The above treatment removes suspended solids and free and emulsified oils. The process also precipitates and removes heavy metals and phosphates, adjusts pH and eliminates colloidal color caused by paint. Chemical treatment does not, however, remove dissolved BOD which is caused largely from solvents.

On-site treatment of sanitary wastes is made necessary by the rural setting of the plant. The sanitary wastes are pumped to an extended aeration activated sludge plant consisting of two 30 hour detention aeration tanks, two 150 square feet clarifiers and a chlorine contact chamber.

## THE CONCERN OF DISSOLVED ORGANICS

The original wastewater treatment facilities continue to function as designed since startup in 1967. The MOE, from the beginning of operations, indicated some concern over any excessive BOD loading to the receiving stream because of its very low assimilative capacity. The situation became more serious in 1977, when Ford changed the electrocoat paint process from an anodic to a cathodic type paint to improve corrosion protection of cars. Cathodic paint composition contains increased solvents, which in turn caused a many-fold increase in the BOD of the wastewater discharged to Dodds Creek. At this time it became necessary to consider adding additional treatment facilities to remove the BOD caused by dissolved organic compounds.

Table 3 characterizes the dissolved organic content industrial wastewater after batch treatment following the switch to the cathodic system. Also shown are MOE objectives for the receiving stream. Because of low stream flow, the objectives, in effect, apply to the plant discharge. As the total plant discharge consists of approximately one half uncontaminated cooling water, the requirements for the wastewater treatment facilities are somewhat less stringent.

TABLE 3

### DISSOLVED ORGANICS CONCENTRATIONS AND STREAM QUALITY OBJECTIVES

| | BOD (milligrams per litre) |
|---|---|
| Industrial Wastewater following Batch Treatment | |
| - average | 400 |
| - 90% of the time less than | 500 |
| - 97% of the time less than | 560 |
| Receiving Stream Objectives | |
| - May 16 - October 14 | 3 |
| - October 15 - May 15 | 7 |

## LABORATORY SCALE TREATMENT PROCESS SIMULATION FOR DISSOLVED ORGANICS REMOVAL

The initial laboratory characterization of batch treatment effluent identified the following:

- o BOD/COD is not readily removed from the wastewater by air stripping.
- o The wastewater is not toxic to micro-organisms present in domestic wastewater treatment plants.
- o BOD/COD ratios indicate that much of the COD is biodegradeable.

These data suggested that the wastewater is amenable to aerobic biological treatment, a process which can be highly cost-effective in removing dissolved organics from wastewaters.

Consequently, a lab scale biological process simulation was undertaken to determine:

- o Extent to which aerobic micro-organisms can remove COD.
- o Rate at which BOD/COD is removed biologically.
- o Significance of temperature to this process.
- o Biomass growth rate.
- o Biomass settling characteristics.
- o Ease with which oxygen in air can be put into solution in the wastewater.

A series of 6 litre, aerated, manually-fed reactors were used to determine values for these design parameters.

Figure 2 illustrates the kinetics of dispersed phase aerobic biological treatment for this industrial wastewater at a temperature of 20°C. The top portion of the Figure shows that, at this temperature, dissolved COD can be reduced to about 20 milligrams per litre at food to micro-organism (F/M) ratios of less than about 0.3 per day. Similar tests showed that at 8°C, the feed ratio must be reduced to no more than 0.1 per day for a similar level of treatment. The near zero slope of the curve at these low loading ratios shows that the biodegradeable component of the wastewater has been reduced to a very low level. Direct testing indicated a residual dissolved BOD of about 6 milligrams per litre. Related testing suggested that, in addition to the F/M constraint, a minimum contact time of about 1 day (at 20°C) was needed to ensure a very high level of biological treatment.

The bottom portion of Figure 2 illustrates sludge accumulation rate as a function of feed rate. The rates indicated are not unusual for a system where there are few solids in the influent, about 15 milligrams per litre to contribute to the mass of mixed liquor solids. At the food to micro-organism feed rates consistent with a high level of treatment, a sludge age of about 30 days is indicated. This implies relatively small quantities of waste activated sludge will be produced.

Activated sludge in this type of system, while settleable, tends to be light. Thus, return sludge concentrations may be less than 10,000 milligrams per litre and clarifier mechanisms should minimize turbulence in the sludge collection zone.

It was found that chemical batch treatment effluent had an oxygen transfer coefficient of about one half that of distilled water. This value increased during biological treatment to a maximum of about 0.7 that of distilled water. Oxygen saturation values of the three waters were, however, similar.

In summary, lab tests confirmed the suitability of an aerobic biological process for treating this wastewater to a high degree and provided data for evaluating design alternatives, sizing process components and selecting equipment types.

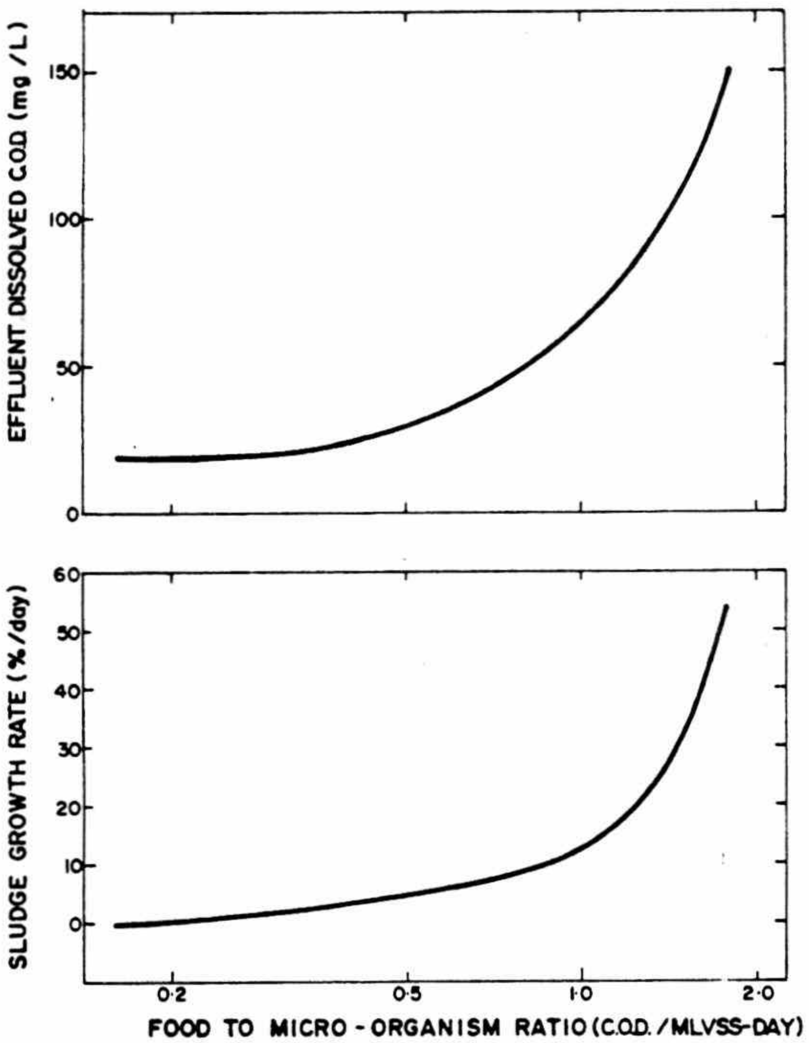


FIGURE 2

KINETICS OF BIOLOGICAL TREATMENT

## DESIGN FEATURES FOR DISSOLVED ORGANICS REMOVAL

Significant features of the design which was developed include the following elements.

- A high level of treatment is needed; thus back-up is installed for key process units. Back-up included providing "firm capacity" for pumps and blowers and a layout with two aeration sections and two clarifiers.
- Hydraulic equalization is installed at the wet well to transform surges of flow from batch tanks to a near constant flow to the biological process.
- Flexibility is available for varying wastewater characteristics. The aeration tanks are capable of approximating a plug flow reactor, but can be modified by valving to a complete mix or an intermediate type of configuration. The aeration vessels have a total hydraulic retention time of three days at design flow. This sizing, based on constraints of the biological process, also provides a capability for significant equalization of influent flows in the aeration tanks.

- This "low rate" type of biological system is inherently capable of dealing with variations in organic loading. Since the sludge age is high, reduced loading rates have little effect on biomass characteristics. Adequately low F/M ratios can be obtained with mixed liquor volatile solids of about 1000 milligrams per litre.
- Static mixers are mounted over coarse bubble diffusers to provide the high level of mixing needed, while oxygen transfer is reasonably efficient, and the risk of orifice clogging is very low.
- Effluent from the sanitary wastewater extended aeration plant is added to the new biological facility both for improved sanitary wastewater treatment and to supply nutrients to the nutrient-poor industrial wastewater.
- Induced suction clarifiers are used to efficiently recover and return settled sludge.
- A "traveling bridge filter" is used to remove residual solids from the treated wastewater. This type of segmented, shallow bed device allows ready observation of and access to the filter media, while providing uninterrupted filtration with a single unit. It is less costly than the conventional two to three filter arrangement with standby capacity during backwash cycles.
- Ferric chloride, nutrients, polymer and chlorine solution addition systems are available if needed to assist process performance.
- Waste activated sludge is discharged with any scum from the clarifiers and filter to an aerated lagoon for storage. Supernatant discharges back to the wet well. Sludge age is automatically controlled by valving return sludge to the aerated lagoon for a preselected portion of each day.
- Laboratory facilities are provided at an upper floor of the control building adjacent to the control room. An elevated enclosed walkway provides direct access between this work area and the control room of the chemical batch treatment facilities.

Values for some design parameters selected for the system are presented in Table 4. (Plant layout is shown in Photograph 3.)

TABLE 4

**DESIGN FEATURES**

| | | |
|---|---|---|
| o **Flow** | | |
| **Average** | - | **840,000 I gal/day** |
| **Maximum** | - | **1,740,000 I gal/day** |
| o **Aeration Tanks (2)** | - | **200,000 cubic feet each** |
| o **Clarifiers (2)** | - | **35.5 sq. ft. diameter each** |
| o **Tertiary Filter (1)** | - | **420 square feet** |
| o **Aerated Sludge Stabilization Lagoons** | - | **840,000 I gal.** |

## STAFFING

When the new biological treatment facilities were launched in 1980, four additional employees were assigned to the treatment operations to provide 24 hour coverage and to perform the additional monitoring tests. The operators are stationary engineers with prior water treatment experience, and a stated interest in waste treatment. They successfully completed the MOE course on basic sewage treatment. Several of the operators also attended the MOE course on operating activated sludge plants.

When the new biological treatment plant was ready for start-up in July 1980, Ford Corporate and Divisional Staff representatives, in conjunction with the St. Thomas plant and MacLaren Engineers, developed a training program to insure that all operators received extensive training on the proper operation, maintenance, testing and monitoring of both the existing and new extended and integrated treatment facilities.

During the training program, each operator was given 5 days one to one training on biological plant operation and laboratory testing procedures. Each operator was provided with both a complete book on proper laboratory test procedures, and an operational manual on the new biological treatment facilities. Monthly checks continue to review the operation and provide any additional operational assistance needed. Staff alternate in responsibility between the batch chemical and the biological treatment facilities on a weekly basis, thus maintaining familiarity with all aspects of the plant operations.

A completely new biological laboratory was installed to supplement the existing chemical laboratory. This new facility has the capability to run the following analytical tests:

- Biochemical Oxygen Demand
- Chemical Oxygen Demand
- Dissolved Oxygen
- pH
- Mixed Liquor Suspended Solids
- Mixed Liquor Volatile Suspended Solids
- Settling Tests
- Chlorine Residual - Amperometric
- Grease and Oils
- Total Dissolved Solids
- Total Solids
- Temperature
- Ammonia/Nitrogen
- Total Phosphorus
- Phenols
- Sludge Volume Index

Additionally, a microscope, spectrometer and several portable composite samplers were purchased. Experience has shown that portable samplers provide much more flexibility within the operations (i.e., following clarification, filtering, etc.) than permanent samplers. In early 1982 an atomic absorption unit was acquired and the operators were trained in its operation to give the plant the capability for accurate on-site analysis of heavy metals.

## PERFORMANCE

Start-up of the biological treatment system involved seeding the filled aeration vessels with a small quantity of activated sludge from the sanitary wastewater extended aeration plant. These organisms flourished in the relatively large supply of substrate. Within two weeks a highly settleable floc had developed and effluent quality had achieved treatment objectives.

Since start-up, the performance of the upgraded treatment facilities has attained or exceeded design expectations. Influent BOD has been less than was originally anticipated due to paint processing changes. Tables 5 and 6 indicate the plant's performance from August 1980 through January 1982.

### TABLE 5

### OVERALL TREATMENT PLANT PERFORMANCE

| | | |
|---|---|---|
| Influent BOD | | |
| Average | - | 115 mg/L (1) |
| Maximum | - | 489 mg/L |
| Effluent BOD | | |
| Average | - | 3 mg/L |
| Maximum | - | 14 mg/L |

(1) Influent average BOD reflects a substantial amount of downtime due to reduced production.

### TABLE 6

### TREATMENT PLANT PERFORMANCE BY MONTH

| MONTH | 1980 | | | 1981 | | | 1982 | | |
|---|---|---|---|---|---|---|---|---|---|
| | Influent Flow (MIGD) | Influent BOD (mg/l) | Filter Effluent BOD | Influent Flow (MIGD) | Influent BOD (mg/l) | Filter Effluent BOD | Influent Flow (MIGD) | Influent BOD (mg/l) | Filter Effluent BOD |
| January | | | | | | | | | |
| Maximum | | | | 0.710 | 193 | 13 | 0.482 | 210 | 12 |
| Average | | | | 0.410 | 84 | 4 | 0.160 | 101 | 5 |
| February | | | | | | | | | |
| Maximum | | | | 0.465 | 124 | 14 | 0.533 | 220 | 11 |
| Average | | | | 0.320 | 51 | 4 | 0.168 | 123 | 6 |
| March | | | | | | | | | |
| Maximum | | | | 0.753 | 489 | 9 | 0.534 | 135 | 9 |
| Average | | | | 0.420 | 142 | 4 | 0.357 | 104 | 4 |
| April | | | | | | | | | |
| Maximum | | | | 0.762 | 250 | 8 | | | |
| Average | | | | 0.468 | 115 | 4 | | | |
| May | | | | | | | | | |
| Maximum | | | | 0.700 | 200 | 10 | | | |
| Average | | | | 0.480 | 113 | 3 | | | |
| June | | | | | | | | | |
| Maximum | | | | 0.764 | 280 | 10 | | | |
| Average | | | | 0.500 | 108 | 3 | | | |
| July | | | | | | | | | |
| Maximum | | | | 0.714 | 237 | 7 | | | |
| Average | | | | 0.350 | 72 | 2 | | | |
| August | | | | | | | | | |
| Maximum | 0.720 | 340 | 4 | 0.751 | 198 | 4 | | | |
| Average | 0.650 | 157 | 2 | 0.470 | 79 | 2 | | | |
| September | | | | | | | | | |
| Maximum | 0.688 | 397 | 8 | 0.317 | 151 | 8 | | | |
| Average | 0.350 | 129 | 3 | 0.220 | 53 | 3 | | | |
| October | | | | | | | | | |
| Maximum | 0.880 | 182 | 5 | 0.322 | 175 | 5 | | | |
| Average | 0.370 | 116 | 2 | 0.219 | 47 | 2 | | | |
| November | | | | | | | | | |
| Maximum | 0.640 | 474 | 9 | 0.606 | 126 | 5 | | | |
| Average | 0.420 | 238 | 3 | 0.240 | 74 | 3 | | | |
| December | | | | | | | | | |
| Maximum | 0.780 | 475 | 10 | 0.510 | 161 | 6 | | | |
| Average | 0.380 | 284 | 6 | 0.220 | 105 | 3 | | | |

This level of performance has been maintained in spite of variations in loading caused by downtimes varying from two days to several weeks interspersed with periods of full production. Typical ranges for organic loadings to the treatment plant and corresponding effluent BOD concentrations are illustrated in Figure 3.

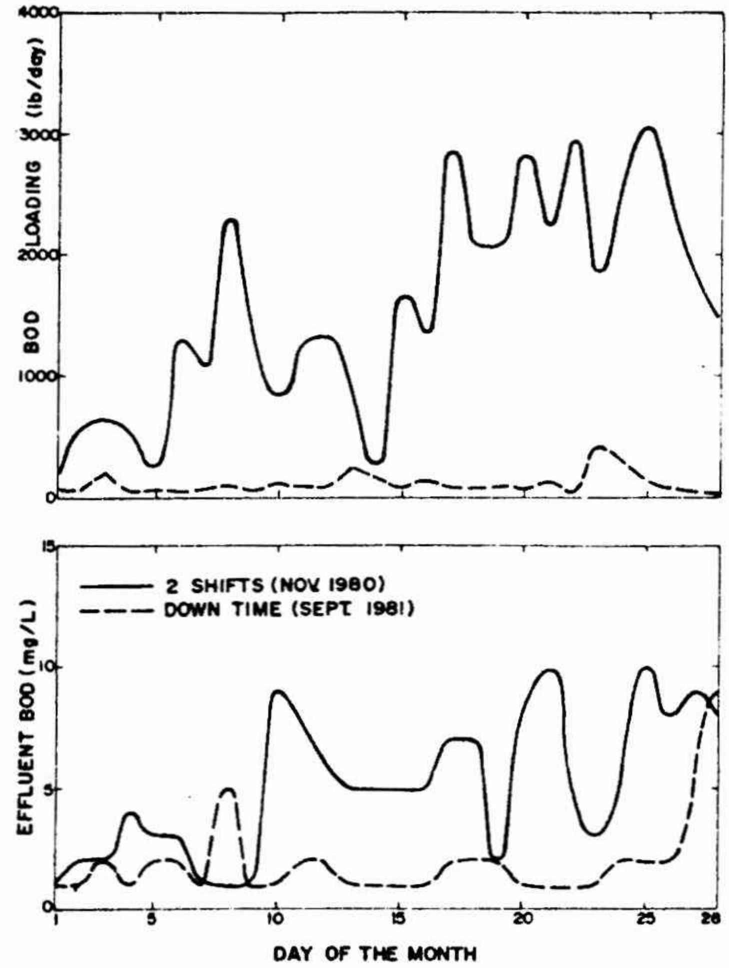


FIGURE 3

EFFLUENT QUALITY

COMPARED TO

ORGANIC LOADING

As with all biological systems, there is concern over maintaining plant performance both during very cold weather and low wastewater flow periods. When these conditions combine, the wastewater cools to the extent that biological treatment rates are lower, and effluent quality slightly deteriorates. However, this effect is very minor and at such times, BOD impact on the stream is low since oxygen demand from BOD isn't any more rapid in the stream than in the treatment plant.

It is interesting to examine the impact of the upgraded treatment facilities on the receiving stream. A water quality monitoring station has been maintained approximately 2 miles downstream of the plant's discharge by MOE. Analyses of grab samples taken approximately monthly are available for the years 1975 and 1978 to 1981. A plot of BOD, dissolved oxygen and phenol concentrations for these years is presented in Figure 4.

Although the data are somewhat sparse, a dramatic improvement in water quality is evident, beginning in 1979 when the permeate was disposed of offsite as an interim measure, and continuing in 1980 and 1981 when the biological treatment and filter systems were in operation.

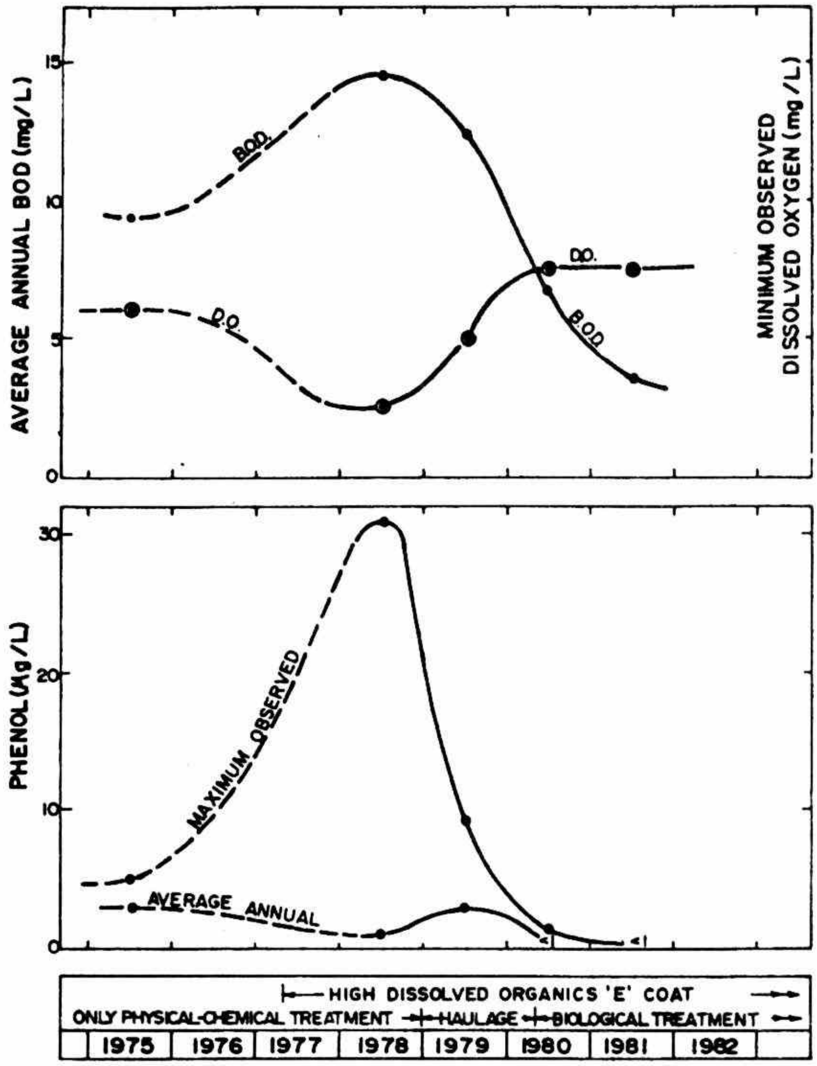


FIGURE 4

**WATER QUALITY IN RECEIVING STREAM**

(STATION 16-0087-013-02)

## SUMMARY OBSERVATIONS AND CONCLUSIONS

Nearly two years of operating experience exists for the integrated wastewater treatment system consisting of chemical coagulation, flocculation and settling in a batch process followed by a biological process for dissolved organics removal. Summary observation and conclusions follow:

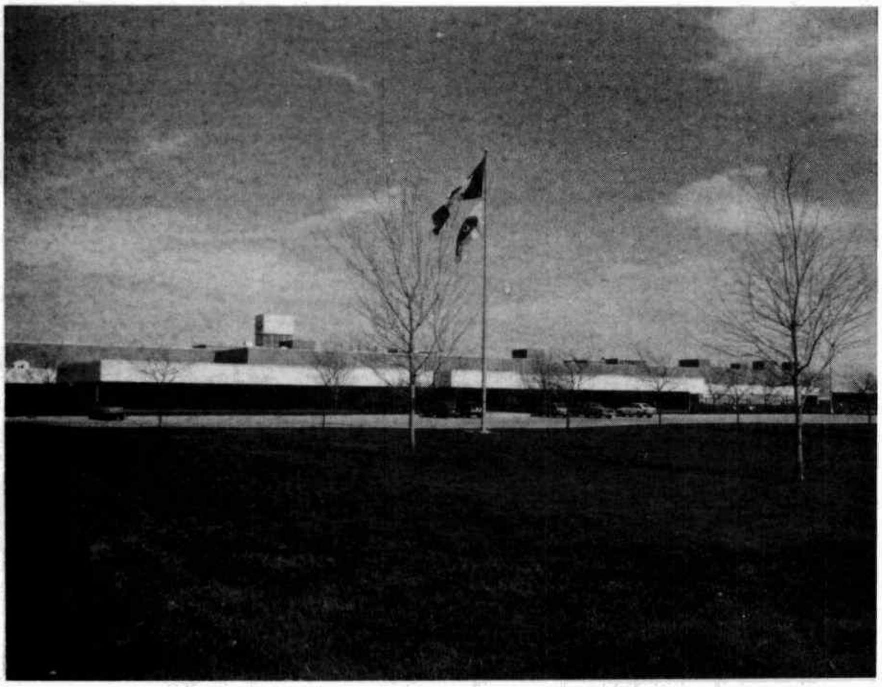
- The dispersed phase biological process has enabled plant effluent to attain the stringent water quality objectives set for BOD on a continuous basis in spite of widely fluctuating organic loadings. This evidence again confirms the ability of the process to perform in a highly effective, efficient and self-regulating manner on provided that:

    a) The substance is biodegradable and produces a settleable floc.
    b) The system is not overtaxed by the presence of toxic compounds such as heavy metals or other incompatible substances such as oils.
    c) The system is designed for peak loadings. Resiliance to load variations can be created through the design of a "low rate" system. A "high rate" system, where, for example, it is necessary to maintain a high concentration of mixed liquor solids in a smaller aeration vessel would not be expected to perform as well.

- The siting of the St. Thomas plant has obvious economic advantages due to adjacent labour forces and transportation systems. It could be said that the siting is not totally ideal from utilities and environmental aspects because of the need for water pipeline construction and more stringent effluent standards than might apply at a larger receiving water.

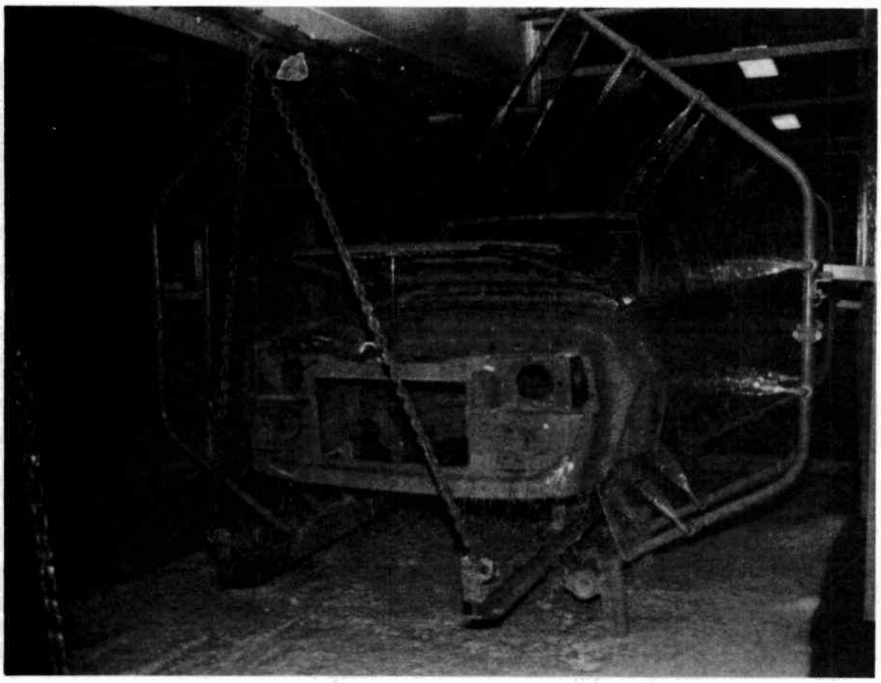
  However, on balance, it would appear that the advantages of the site outweigh any disadvantages. While the total cost of upgrading treatment facilities was about $2,500,000 in 1979 dollars, only a small portion of this (i.e., filters) can be attributed to the incremental additional cost of attaining the more stringent objectives of such a small receiving stream.

- It could be argued that the "impact" of the assembly plant discharge on the receiving water is a positive one. That is, treated wastewater probably compares favourably with natural runoff from adjacent agricultural land uses. More importantly, the wastewater augments flow in an otherwise sluggish to ephemeral stream, thus enhancing the aquatic environment.



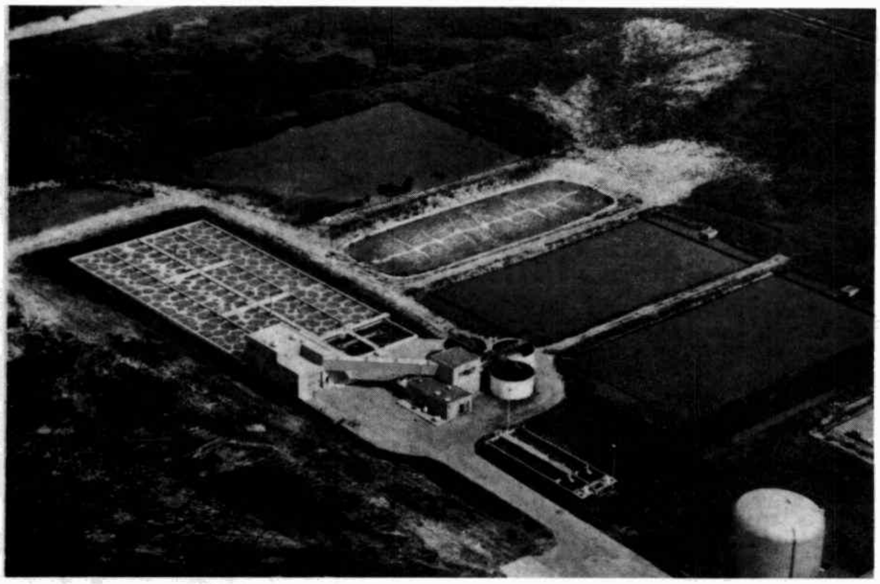
PHOTOGRAPH 1

St. Thomas Assembly Plant



PHOTOGRAPH 2

Electrocoat Painting,
Permeate Rinse Section



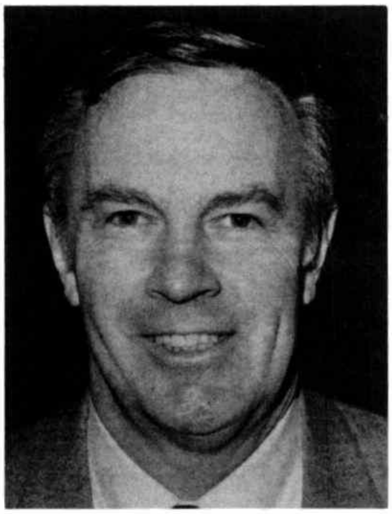
PHOTOGRAPH 3

Wastewater Treatment Facilities

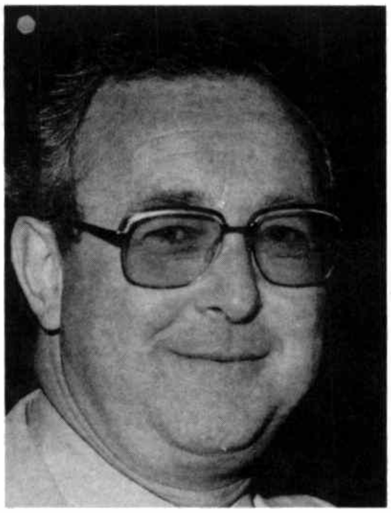
Note 3 Batch Treatment Tanks,
2 Settling Lagoons,
Biological Treatment Unit,
Aerated Sludge Lagoon and
Sludge Disposal Lagoons
in Background

# SESSION III - INDUSTRIAL WASTE MANAGEMENT - PART I

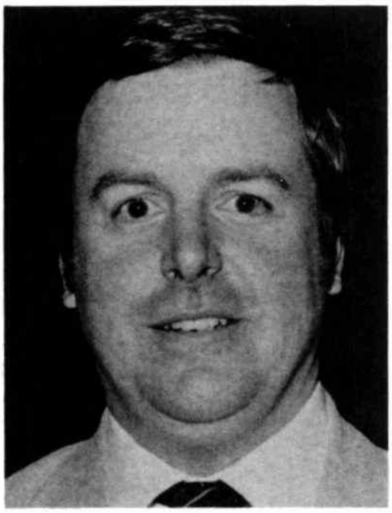
**Chairman:** R. M. Gotts
Regional Director
Northwest Region,
Ontario Ministry of the Environment
Thunder Bay, Ontario



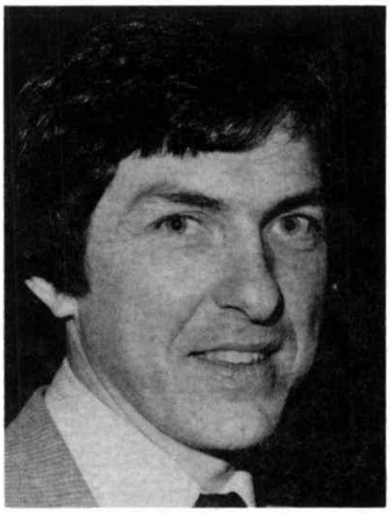
G. A. Douglas, General Manager,
Ontario Waste Management
Corporation
Toronto, Ontario



K. A. Childs
Waste Management Branch
Environmental Protection Service
Environment Canada,
Ottawa, Ontario



Dr. R. B. Pojasnk, Vice-President
Roy F. Weston Inc.
Burlington, Massachusetts



Alun James, Head
Radioactivity Unit
Waste Management Branch,
Ontario Ministry of the Environment
Toronto, Ontario

# EVENTS OF THE LAST YEAR AND POSSIBLE FUTURE DIRECTION

by

G. A. Douglas
General Manager
Ontario Waste Management Corporation
Toronto, Ontario

Good morning! I think it's only proper that I acknowledge the generous number of delegates in attendance at the first session of the day.

It may not be entirely fair that your efforts to arise early be rewarded with an historic dissertation as the first presentation. However, those of you who had difficulty in staying awake during history class may take comfort from the fact that any chronology of events associated with the Ontario Waste Management Corporation will not be lengthy. The Corporation is less than two years old! Historians have barely had time to record its existence!

However, the OWMC has initiated a significant concentration of activities during this short time; and I'd like to take this opportunity to bring you up to date on the status of our activities.

During the next 15 to 20 minutes I'd like to do three things:
- outline briefly who OWMC is,
- tell you something about our activities, and
- identify for you some key issues involved in our work.

As many of you know, the formation of the OWMC was announced in the Ontario Legislature on November 25, 1980, by the Minister of the Environment of that time, Dr. Harry Parrott.

Purely as an aside - those of you who can recall the political situation of that time, which saw a minority Government in office, will probably agree with me that future historians will be hard pressed to describe the Corporation's "conception" as being anything even close to "immaculate".

However, the Crown Corporation, to be known as the Ontario Waste Management Corporation, was formally established by Bill 90, which received third reading in the Ontario Legislature on July 2, 1981.

Bill 90 charges the Corporation with rather broad responsibility.

However, simply stated, we have two basic objectives:
- to design, construct, and operate a province-wide system for the treatment and disposal of industrial waste, and
- to develop a long term program to assist in the reduction and recycling of industrial waste.

OWMC policy is formulated by a board of seven directors, The Board was appointed in early 1981 and has met regularly since then.

I am noting their names and backgrounds by way of emphasizing the broad areas of interest they represent:

- Dr. Donald A. Chant serves as Chairman of the Board and is also President of the Corporation, he is a Zoologist, a former Vice-President and Provost of the University of Toronto, Founder of Pollution Probe and, most recently, Director of the Joint Centre for Toxicology at Universities of Toronto and Guelph.

- Harvey Polk serves as Vice-Chairman of the Board, he is Chief Engineer, Specialized Engineering at the Steel Company of Canada Limited.

- Edith Fuller, Mrs. Fuller is Mayor of the Town of Haldimand (formerly Cayuga), in the regional Municipality of Haldimand-Norfolk.

- Frank Sommer, Mr. Sommer is a soyabean and hog farmer in the Cayuga area and a Director of the Ontario Federation of Agriculture for Haldimand West.

- James King is Chairman of the Board of Alfa-Laval Limited, in Peterborough.

Stephen Rodd, is a Professor at the School of Agricultural Economics & Extension Education; University School of Rural Planning & Development, University of Guelph.

- Firman Bentley, Mr. Bentley is Group Vice-President, with global responsibility for rubber and plastics, Polysar Limited.

The activities of the Corporation are guided by a Senior Staff of five people including Dr. Chant, who, in addition to his duties as chairman, is also President.

In addition to Dr. Chant -

- I am General Manager of the Corporation. Edgar Schmidt, our Project Director, was previously employed by Polysar Ltd., where he held responsibility for the construction of several multi-million dollar projects in Canada and elsewhere.

- Also reporting to Dr. Chant are Dr. Barry Mitchell, our Director of Corporate Planning and Development, who comes to us from the University of Toronto, and

- Michael Scott, our Director of Communications, formerly Director Corporate Communications, Inco. Ltd.

We're adding a Finance and Administration Director to our staff next month, and other key appointments will be made as appropriate.

Our total staff at this time is eleven.

When the Ontario Government first announced the creation of OWMC, it directed the Corporation, by means of an order in council, to a parcel of land in South Cayuga (30 miles south of Hamilton, near the north shore of Lake Erie). The Government also exempted the project from the provisions of the Environmental Assessment Act.

However, it should be pointed out at this time that Dr. Chant and some of the Corporation's Directors accepted their appointments to the Board with the following conditions:

Firstly, that the Corporation would conduct a thorough investigation at the proposed site at South Cayuga and decide whether a waste treatment centre should be built there or not.

Secondly, in the event the Corporation's decision was in favour of building facilities at South Cayuga, the project would have to be subjected to public hearings.

Consistent with the Board's policy that no decision be reached regarding South Cayuga until a thorough investigation of the site was conducted, the firm of Gartner Lee Associates Limited was retained in May of 1981 to undertake a geological and hydrogeological assessment of the South Cayuga Site. They were assisted in this connection by International Environmental Consultants.

In August of 1981, Proctor and Redfern Limited, Engineers and Planners, were engaged as prime consultant to the Corporation. They have included in their core staff, representatives from the Ontario Research Foundation and Weston Designers/Consultants.

In November 1981, Gartner Lee had completed preliminary field tests on the proposed South Cayuga site, and reported their findings to the Corporation.

The next two shots show Gartner Lee personnel supervising the digging of test pits in the proposed site area. It was these test pit digs that confirmed the existence of buried drumlins just under the soil surface.

This diagram portrays the clay going right to bedrock; however, it also depicts a now famous (or infamous) drumlin extending from bedrock to surface through the clay.

The combination of buried drumlins in addition to surface drumlins, areas of sedimentary bedrock near surface, the potential for flooding and, finally, the presence of close to 200 gas wells (some of them abandoned and unmarked) led to the assessment of the South Cayuga site as having only "marginal" potential for a waste management site. The white perimeter line on the map defines what was known as the "Order in Council Boundary".

The Order in Council that provided the OWMC with its original terms of reference directed the Corporation to find a site within these boundaries.

These small green marks indicate buried drumlins. The larger cigar-shaped areas of green identify surface drumlins.

This large red area is a portion of the Onondaga Escarpment, which rises to surface in some areas.

The blue area depicts the flood plain of small streams flowing into the Grand River at this point.

The gas wells were too numerous to show.

The small yellow area identifies an area of sand and gravel.

The Corporation's Board of Directors unanimously rejected the site, and their decision was announced at a press conference held on November 18, 1981.

Now, the big question!? If not South Cayuga - where then??

Immediately following the rejection of South Cayuga, the OWMC set out to develop a step by step approach to developing an industrial waste management facilities system for the Province.

Concurrent with Gartner Lee's assessment of the South Cayuga area, Proctor and Redfern Limited had been conducting two non-site specific studies -

Their first task was to provide OWMC with a detailed report of the quantities, types and geographical distribution of industrial wastes being generated in Ontario today, along with a projection of waste generation in the future. This study is, of course, fundamental to the entire project.

Proctor & Redfern's second task calls for the preparation of a world-wide inventory of technology that might be employed to recover, reduce, treat, destroy or store the waste that are identified by their market study.

These two major studies have been incorporated into a five step "Facilities Development Process" which involves information gathering, evaluation, selection, preparation for public hearings, and finally the public hearings.

We are nearing the completion of Phase I; the "Description" or "Information" gathering phase.

- Here it is in more detail!

The number of studies has grown significantly since our rejection of South Cayuga. The studies fall into three general categories:

Engineering information

Environmental information

Planning information

You'll see in the 3 boxes a few examples of the type of studies that are being undertaken at this time. They're all non-site specific, of course.

Now the final product of this Phase I will be a list of possible facilities system options. I won't even hazard a guess at this time as to just what type of treatment and disposal facilities might be identified in Phase I. However, the facilities could, for example, be fully integrated on one site or, for the purpose of discussion, they might be strategically dispersed throughout the province.

You'll appreciate, I'm sure, that the factors that would be desirable for an incinerator or a physical/chemical treatment plant probably wouldn't be the same as the factors that might lead one to a site for secure landfill. Soon we'll have to marry certain generic treatment technologies to certain waste classification and arrive at a number of system options.

The Corporation is committed to provide the results of our studies and consult with the public at each stage of the facilities system development process.

Let's have another look at the complete process. You can see that the product of Phase I (a number of possible system options) would involve public consultation prior to proceeding to Phase II, the evaluation phase. The product of Phase II would be a list of preferred system options.

The product of Phase III, a final selected system.
Phase IV, a proposal, and
Phase V, public hearings.

Before concluding my presentation, you may be interested to know about some of the policy decisions that the Corporation has taken and some of the decisions that are still pending.

Policy decisions that have been taken by the OWMC include the following commitments -

1. That state of the art technology will be employed to treat wastes.

2. That only treated wastes will go to landfill. While secure landfill will be a necessary component of the waste management system, the emphasis will be on the treatment of wastes.

3. The Corporation has agreed to provide funds for participants in the public hearings.

4. The results of all major studies will be released to the public.

5. There will be public consultation prior to making major policy decisions.

Some policy decisions that have not been taken are -

1. There has been no decision on whether the various treatment & disposal facilities will be consolidated on one site, or whether they will be located on several sites.

2. Definitely no decision yet regarding locations for any of the facilities, and

3. No decisions have been reached regarding a choice of technologies that will be used to treat the wastes.

In conclusion I hope the foregoing review will be of interest to you.

If you have any questions regarding the Corporation's activities, I'll be pleased to try and answer them.

# PCB TREATMENT AND DESTRUCTION TECHNOLOGIES

by

Ken Childs
Chief
Technology Services Division
Waste Management Branch
Environmental Protection Service
Environment Canada
Ottawa, Ontario

Ten years ago a paper such as this would never have been given -- not because this paper is so outstanding but because the PCB situation had not manifested itself. Also, if one were hypercritical it could be argued that there was no need to embark on a program of technology development and technology transfer (the like of which has occurred in the past few years) when technologies already existed for destroying or treating this material. The need to provide facilities for the treatment or destruction of PCBs came about subsequent to the enactment of the Environmental Contaminants Act in the 1970's. This Act which does not prohibit the production of PCB's does restrict their use and release to the environment. Since that time these materials have been entering the waste stream from activities such as retro-filling and equipment replacement. At this time no approved facilities exist in Canada for the efficient treatment or destruction of PCBs and, because the Canada - U.S. Border is closed to these PCB waste materials, they are being stored. As a personal observation, I wonder if the bulk storage of these materials represents a greater potential hazard than the "hazard" represented by their continued use or by their storage in smaller quantities close to the original locale where they were being used. During the past few years we have seen the emergence of a proliferation of new technologies specifically designed to treat or destroy PCBs and in Environment Canada we continue to receive proposals to develop even more methods. We started to ask questions. a) Didn't we already receive details of this method from another company last week? b) Do we in fact need any more methods? and c) Do the methods that presently exist have flexibility allowing for the destruction of the various forms and concentrations of PCBs? In addition to this we, and the provincial jurisdictions across the country were facing and continue to face a continuing problem; where (in the absence of facilities and in the presence of a closed border) will these materials be stored? We have another problem -- the one of just keeping track of the methods and systems that were in place or available. It appeared to us that there was frequently at least a duplication and most certainly a similarity between many of the systems. It was in this environment, an environment of a plethora of technology and contradictory or similar claims that we decided to undertake an inventory of methods currently available for the destruction or treatment of PCBs and materials contaminated by PCBs.

If I'm allowed to place a dedication in the front of the report when it is published I will probably re-word one of the most famous lines of an English poet and put "How many times can I destroy you, let me count the ways". When we embarked on this project we really had no idea how many systems or methods there were and the consultant who undertook the project, upon which this presentation is based, started from substantially the same level of under-estimation. Both we and the consultant thought that there maybe twelve or fifteen methods but after a preliminary examination the consultant identified in excess of eighty systems ready and willing to go. The consultant pursued the study even though the task was of a somewhat greater magnitude than he had anticipated and a publication based on the study will be available from Environment Canada later this year. The study was not designed to provide comparisons but to provide a listing of the systems available and, when possible, provide financial data with respect to capital costs and unit treatment costs. The sources of information used by the consultant and, subsequently, by ourselves, included direct contact with manufacturers, promotional and proprietry information from manufacturers, earlier studies, earlier inventories and trade and technical journals. Some of the costing was provided by the manufacturers and some was developed by the consultant.

With apologies to those who spend much of their time in and around PCBs and to those of you who are chemists, I submit Fig.#1 as an indicator of what PCBs are and to identify the nature of the properties that they exhibit including some of the hazards which are attributed to them. The most toxic of the family are TCDD and TCB, and of growing concern are the dioxins and dibenzofurans particularly as they might occur as a result of re-combination during an oxidation process.

There is considerable dispute with respect to the magnitude of the "problem" of PCBs and the length of time that we will experience the problem. To complicate matters inventories have been taken many of which will have varying quantities, varying distributions, and varying opinions with respect to concentration and nature of the materials. The best figure that I can present with respect to the quantities in use or in storage in Canada is 1.6 million kilograms of which 1.3 million kilograms is in private storage awaiting treatment or destruction. Of this total quantity fifty to seventy per cent will be PCBs the rest being carrier material. In Canada the bulk of the PCBs used have been used in transformers whereas in the United States they have been used in capacitors. This may allow for easier disposal in Canada. It is anticipated that, in Canada, there will be an attrition period of approximately forty to fifty years, this of course could be changed if Canada adopts a phasing out procedure requiring that those PCBs currently in use be removed from use and destroyed.

In the report presented to us by the consultant three main technology groups were identified for review, a) incineration and its variations b) chemical processes and c) physical/chemical processes.

The first group, conventional incineration. This is a process which has been utilized for many years wherein organic materials are oxidized creating emissions such as $CO_2$, $H_2O$ plus inorganic residues. When PCBs are incinerated there is also a by product of HCl which is removed by scrubbing. The standard criteria for destruction of PCBs is a residence time of approximately two seconds, a temperature of twelve to sixteen hundred degrees centigrade and an excess oxygen of two to three per cent. Three conventional incinerators are described in detail in the report.

Firstly, the incinerator operated by Rollins Environmental Services in Deer Park, Texas. This incinerator is capable of accepting both solids and liquids, it uses auxiliary fuel, gas, or oil, and operates at a temperature of approximately fifteen hundred degrees centigrade. The residence time, excluding the residence time in the rotary kiln, is approximately two to three seconds. Details of the incinerator are shown in Fig.#2. A risk analysis was undertaken in this instance and it was determined that there would be one additional case of cancer for every fifty thousand persons "exposed" to the facility. This is considered to be an extremely low risk, particularly because of the nature of the assumptions which went into the analysis.

The second incinerator described is operated by Energy Systems Company (ENSCO) Eldorado, Arkansa, details of the incinerator are seen in Fig.#3.

This incinerator is also capable of handling both solids and liquids with the solids being introduced into a rotary kiln after being processed in an enclosed shredder. Operating temperatures are twelve hundred degrees in the rotary kiln and one thousand and forty in the after burner. Products of combustion are neutralized using a slurry mixture of caustic and lime before being discharged to the environment. Destruction rates are noted to be 99.99998%. This incinerator has a capacity of one hundred and ten to one hundred and eighty kilograms of PCBs per hour depending upon the nature and PCB concentration in the feed stock.

Incinerator number three is the incinerator operated by the Dow Chemical Company in Midland, Michigan. This incinerator was selected as being fairly typical of the liquid industrial waste incinerator commonly available "off the shelf" and presently operating in a number of locations for destroying wastes other than PCBs. This incinerator is limited to destroying liquids and operates at a temperature of nine hundred to one thousand degrees centrigrade with a residence time of three seconds. The capacity of the incinerator is forty kilograms per minute and there is a destruction efficiency of 99.99%.

There are approximately two hundred installations of this type of incinerator representing approximately sixty different suppliers.

The configuration of this type of incinerator is shown in Fig.#4.

To summarize the conventional incineration situation: These incinerators are fixed (i.e. not portable) and are fairly standard in their design. Frequently these are operated in conjunction with an industrial plant and are therefore owner/operated which in turn suggests that the operation is usually of a high calibre being both responsibly maintained and operated efficiently. If one was allowed a prediction it would be that this type of incinerator will become more commonly used if the apparent trend to on-site waste management takes over.

I should note that in addition to those incinerators identified earlier there are eight other incinerators of this type, either currently being used for the destruction of PCBs or, in the process of receiving approval to destroy PCBs.

The next section in the report deals with what are identified as variations of incineration. Included in this category are systems such as kilns, boilers, furnaces and adaptations of these processes or systems. Most frequently these systems are directed towards low level concentrations of PCBs and are usually restricted to low feed rates.

The first group in this category is high efficiency boilers. In the United States parameters have been established allowing high efficiency boilers to be used for the destruction of PCBs. These are-- a maximum PCB concentration of five hundred ppm, a boiler heat release in excess of thirteen X $10^6$ kilo-calories per hour, stack emissions of CO of less than fifty ppm for oil or gas fired furnaces and one hundred ppm for coal, and a minimum of three per cent excess oxygen. In addition to these requirements there must be routine monitoring of stack gases, feed rate and overall performance. The Electrical Power Research Institute in the United States, which has a close relationship with many of the boiler operators, suggested that higher concentrations of PCBs should be considered. Generally high efficiency boilers work in a temperature range of fourteen hundred to seventeen hundred degrees centigrade, there is normally a residence time of one to four seconds with feed rates varying between one hundred and fifty to three hundred kilograms per hour. Destruction efficiencies of 99.99% appear to be the maximum achievable. Normally high efficiency boilers have no scrubbing facilities resulting in the discharge of HCl to the atmosphere. The operation of high efficiency boilers is a highly developed technology and the technology of the PCB feed system, although not as highly developed, is a simple matter and can be interfaced with the boiler very easily.

To summarize this process: It is a proven technology, controls are simple and adequate, firing systems are variable depending upon the fuel source and configuration of the boiler. The impact on the environment should be minimal. One of the major advantages is that many of owner/operators of the boilers are the owners and users of the PCBs which means that there is a vested interest "in house" in destroying the wastes. In such cases transportation factors can be minimized. It should be noted that, at this time, there are eighteen operational systems currently in use in the United States.

The next system which I would like to refer to is the destruction of PCBs in a cement kiln. Destruction in a cement kiln is a well understood process and is a proven acceptable technology. Despite this, great difficulty has been experienced in getting these systems in place, for this particular purpose, especially in Canada. The history surrounding the Mississauga test burn of PCBs is well known and this sociological experience has probably retarded opportunities to use this process in other locations both here and in the United States.

In cement kilns the operating temperature is in the order of twenty-one hundred degrees centigrade with a residence time of up to thirty seconds. Both the temperature and residence time are well in excess of the requirements needed to achieve total destruction of the PCB molecule. What should also be noted about the cement kiln operation is that the chlorine in PCBs can actually be of value in the process of making cement. Feed stock for a cement kiln operation can be up to fifty-five per cent PCB and destruction rates can exceed 99.9%. It is difficult to establish a unit cost for a cement kiln operation because the value of the PCB material as a fuel can vary from location to location and even from load to load. Generally the problems associated with cement kiln operation are associated with dust in the kiln and reactions with the refractory which may cause higher than average maintenance activity. At the present time there are four kilns in the United States plus one in Puerto Rico capable of taking PCBs as part of their feed stock. Included in these four is the Peerless Cement Kiln in Detroit which operated at a temperature of thirteen hundred degrees, a dwell time of twelve seconds and achieved a destruction efficiency of 99.99%, but this activity was abandoned due to public pressure. I understand that discussions are underway between the State of California and Genstar with the hope that kilns in California might be used for the destruction of PCBs. A typical configuration for a kiln is shown in Fig.#5.

Another example of co-treatment, where the original use has been supplemented by the utilization of the process for destroying waste materials, is the use of an aluminum melting furnace owned and operated by the Aluminum Company of America in Davenport, Iowa. In this case the furnace is used for company wastes only. PCBs having a concentration of three hundred and fifty ppm are destroyed in an environment having a temperature of eleven hundred and fifty degrees centigrade.

The last section dealing with the variations on incineration is directed toward shipboard incineration, a concept which can cause emotions to rise. There are a number of obvious reasons why this process can find favour particularly the fact that where the destruction takes place there is no immediate public to raise objections. However, the more cynical observer might suggest that putting a full load of hazardous waste to sea and then burning the material in locations where operating circumstances are variable and monitoring limited to on-board capabilities is, at best, a risky venture. The most famous of the shipboard incinerators is the

Vulcanus operated by Chemical Waste Management. This ship recently undertook a cruise in the Gulf of Mexico and destroyed thirty-seven hundred tonnes of "pumpable" PCB contaminated materials. The incinerators are injection type incinerators operating at a temperature of fifteen hundred to sixteen hundred degrees centigrade. It is reported that these incinerators achieve a destruction efficiency of 99.9% and that no dioxins have been identified in the air emissions.

The next section of the report deals with what we might call novel incinerators or higher technology oxidation processes. Included in this group are processes such as oxygen incinerators, fluidized bed, molten bed, diesel engines and plasmas.

The first one that I would like to deal with is the system developed by Pyro Magnetics, a company operating out of Whitman, Massachusetts. This portable system is shown in Fig.#6 and you will note that it includes a kiln, a furnace, oxidizer and scrubber. Solid wastes, depending upon their nature, are fed into either the rotary kiln or into the patented SMT furnace. Temperatures in the kiln are in the order of nine hundred and eighty degrees centigrade and in the furnace they reach sixteen hundred and fifty degrees centigrade. Liquids are injected directly into the oxidizer as are the off gases from either the kiln or the furnace. Oxidizer exit temperatures are in the order of twelve hundred degrees centigrade, dwell time in the oxidizer is at least two seconds. The oxidizer has recently undergone tests in the United States directed towards obtaining approval to destroy PCBs. It is understood that these tests have been fully satisfactory. It should be noted that at the time of presenting this paper that the full waste management system (i.e. kiln, furnace, oxidizer and control trailer) have yet to be tested as a complete treatment train. Destruction efficiency is reported to be in the order of 99.9999%. It should also be noted that this operation does need a small lagoon area for receiving the scrubber water.

The next process which I'd like to dwell on very briefly is the chemical plasma which has been developed by SJT consultants here in Toronto. This system is currently in a holding position pending the outcome of discussions between the developer and M.O.E., I will therefore restrict my comments to reminding you that this process has been developed from the MHD technology and involves the destruction of materials, such as PCBs, in a pure oxygen environment. Temperatures up to five thousand degrees centigrade are anticipated. There is the by-product of HCl which is neutralized by the injention of a caustic mix. This process obviously is higher technology and could be one of the many emerging technologies which will be acceptable in the future.

The molten salt system developed by Rockwell International has been the subject of considerable attention. Environment Canada has, this past year, supported optimization tests of this process. It is now abundantly clear that this process does have a very high level of destruction efficiency but may be limited in its application due to relatively high unit costs. In this system wastes are introduced into a bed of molten sodium carbonate. It operates on the theory that there is a heat transfer between the wastes and the molten bed, the resulting gases pass through the melt and emerge as clean emissions. Optimization tests indicate that the capacity is dependent upon the rate that air is introduced into the system. Destruction rates recorded in recent tests indicate a destruction rate of at least 99.99999%.

Another system developed by Rockwell is the fluidized bed. The fluidized bed is a well known and commonly understood technology and I should point out that this system is readily available because it was developed by public funds. In the Rockwell system the fluidized bed is comprised of sodium-carbonate plus a chromium oxide catalyst. The system is comprised of two beds, the first one having a temperature of six hundred degrees and the second bed, which is in series, with a temperature of seven hundred degrees which acts as an after burner. PCBs are introduced into the second reactor. A destruction rate of 99.9999% is achieved. One of the features about the system which may make it attractive is that it may be made portable.

Two other fluidized bed systems are identified. One developed by Systech used for the destruction of phenolic wastes and the other developed by Union Oil which has been used for destroying in-house refinery waste.

One of the technologies which we, in Environment Canada, are interested in is the utilization of the diesel engine as a means of destroying PCBs. The D and D group in Smithville have been responsible for most of the development work in Canada. Limited runs of the engine have been undertaken in Canada but three hundred hours of running in England has produced promising results. The diesel engine can take up to seventy-five per cent askarel with the balance being made up of regular diesel fuel. The PCB material is injected into the combustion chamber where a destruction rate in excess of 99% is achieved. As with many other systems there is a need for a scrubber due to the generation of HCl. One of the most attractive features about this system is the fact that it also could be made portable allowing for the process to go to the waste. By limiting the length of time that the system would be in any one particular location the chances of getting public approval might be increased.

The next major group examined in the original study is the group identified as chemical processes which include chemical dechlorination, radiant energy processes and low temperature oxidation processes.

Over the past few years we have seen a number of chemical dechlorination processes appear on the scene, all of these processes work on the principle of destroying the PCB molecule by removing the chlorine atom. The most common re-agent in this process is sodium. Energy to achieve the destruction is derived from the chemical reaction. The reaction usually occurs in an inert atmosphere to minimize re-agent use and to reduce risk of fire. Usually the products of dechlorination processes are the reusable oil, sodium chloride and some solid wastes which, in the United States, are allowed to go to specified land fills. Time and space do not permit me to discuss all of the processes in detail, these are described in some detail in the report and as you will see there is a similarity between the processes which would make descriptions of all somewhat repetitive and redundant. I propose to give some sparse details on just a few of the processes.

(a) The process developed by Goodyear. In this process sodium napthalyde is the re-agent and the temperature of the reaction is between one hundred and fifty and one hundred and seventy degrees, the controlling factor in this process is the reagent/chlorine ratio which ranges between fifty or one hundred to one. The time taken for the reaction, that is the time between introduction of the PCB materials and optium destruction is approximately one hour. The system operates on materials having a PCB concentration of one hundred and twenty ppm which is reduced to a concentration of two ppm in the effluent.

(b) The PCBX process developed by the Sunohio Company. In this case the reagent is proprietary. The capacity of the system is approximately 2.3 cubic metres per hour of PCBs. The effluent is subjected to GC analysis to determine PCB concentrations. A typical run involves a waste having a concentration of three thousand ppm PCB which will be reduced to two ppm in the product. In this case the unit cost is somewhere between $.80 and $1.30 per litre. It should be noted that this process cannot be used for aqueous wastes.

(c) The Accurex system is an adaptation of the Goodyear process using another proprietary reagent. The capacity of the system is just under one cubic metre per hour and the products of this process are sodium hydroxide, sodium chloride and oil. PCB concentrations in the feed of one thousand ppm are reduced to concentrations of two ppm in the products. However, the company claims that higher concentrations in the waste streams could be tolerated. The cost per litre for this system is reportedly $.70.

(d) The PPM system also uses a proprietary reagent and the products of the reaction are sodium chloride and oil with air emissions of nitrogen and hydrogen. Typically concentrations of two hundred ppm PCB are reduced to non detectable levels. It should be noted that this system is permitted to treat concentrations up to ten thousand ppm.

(e) The NAPEG system developed by the Franklin Institute. In this case the reagent is sodium poly-ethelyne-glycol with a molecular weight of four hundred. The reagent is usually identified as NaPEG four hundred. The operating temperature for this process is approximately one hundred and fifty degrees centigrade. In this process the reagent is shipped to the site and mixed after which the reaction takes place on site. The products of the reaction are sodium chloride, non-toxic organics and decontaminated wastes. This system is currently under review and may achieve some level of popularity due to its simplicity. We were advised that at the present time it costs approximately $1.50 per kilogram to treat PCB contaminated wastes using this system.

One system which should be mentioned because it is slightly different is the system developed by Environmental International. This system is directed towards decontaminating capacitors. The capacitors are rinsed, the metal is salvaged and the rinse material is treated with a proprietary reagent. This system is restricted to handling wastes having a maximum PCB concentration of five hundred and seventy ppm. The products of the process are oil and solid materials which can be land filled in the United States.

The report identifies seven other systems of chemical dechlorination including the systems currently being developed by Ontario Hydro and B.C. Hydro.

Radiant energy systems must be considered as high technology and are still in various stages of development. All of the systems use the same principle of using radiative energy to destroy the PCB molecule.

Included in this classification are the Thagard fluidized wall system, the Plasma Arc process developed at RMC in Ontario which has recently been tested and shows a destruction efficiency of 99.9999% (I believe that a presentation was given to this conference in earlier years describing the process in detail). Other processes in this group include microwave systems including microwave plasma developed by Lockheed and recently abandoned by them due to lack of funding from EPA. The LARC, light activated reduction of a chemical, system uses ultra violet light to destroy halogenated organic materials. Ultra violet light systems have also been developed by Ultrox, Vertac, Pure Water Systems and Oxyphoton.

Oxidation systems which convert PCBs to $CO_2$, $H_2O$ and HCl include the Modar System, identified as the super critical water system, which works at a temperature of five hundred degrees centigrade and a pressure of two hundred and fifteen atmospheres. This system has a destruction efficiency of 99.99% but as of this date is still at the lab scale. The more commonly known oxidation system is the WETOX system which has been described at earlier conferences. This system works at a temperature of one hundred and fifty to two hundred and fifty degrees centigrade but has only achieved a fifty to seventy per cent destruction rate of PCBs and is limited generally to those materials that are easily oxidized. More recently additional work has been undertaken in Michigan and this system could be somewhat more promising than was earlier reported.

The IT Enviroscience oxidation system works at a higher temperature than the other systems and employs a catalyst. It is a variation of the WETOX system but as of yet it has still achieved a destruction efficiency of below 99%.

Finally, in terms of processes, two systems or processes probably are worth mentioning. One is extraction systems whereby the PCBs are extracted from the total waste stream and returned back to the owner for destruction, this obviously does not reduce the total problem significantly and the PCB problem remains -- albeit in concentrated form. At the present time seven companies offer extraction systems four of which are Canadian. All of these systems use well known technology. Lastly the bacterial systems which appear to have limited potential. Polybac has developed a bacteria strain which will work on PCBs and will achieve a 99.8% destruction over a period of eighteen days. Indications are that this technology will have limited application and it will be limited to the lower chlorinated biphenyls.

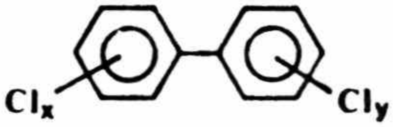
I have indicated on a number of occasions through this presentation, that additional details will be made available through the published report, and the best I could hope to do in this presentation was to indicate to you that there are many systems available, many systems that are both flexible and effective but unfortunately, at this time, in Canada, non-existent. So where does this leave us? We had and have some materials which somebody concluded should be removed from the environment. We have developed means to destroy them, to treat them, to extract them and to concentrate them. We have more than enough methods to choose from. We can guarantee a destruction rate of 99.99999%. For us in Canada with a closed border the problem isn't getting any smaller, in fact if storage is seen as a greater threat than use, the problem may be increasing albeit in fewer locations.

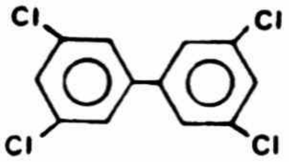
There are a number of proposals that are currently under consideration to provide hazardous waste management facilities, all subject to public scrutiny, public rejection and political decision. I would not like to predict the possibility of success.

Personally I do not know what more we have to demonstrate as far as technology is concerned. If it is, as is most frequently suggested, a question of trust, then we have a very real problem because we have so many systems and an inability to demonstrate them. How then do we develop trust?

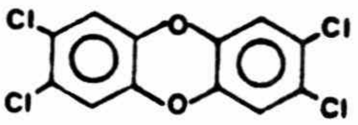
It is to be hoped that the general public, the politicians and the special interest groups will allow us to demonstrate at least one of these systems so that we might develop trust. At Environment Canada we hope that the report that we commissioned, and will publish, will allow the public to see that there are many systems available, it will also indicate that levels of destruction can be achieved which certainly represent no threat to the environment. I hope that the attendees at this conference and other interested persons will avail themselves of this information leading eventually to the public's approbation allowing a system to be put in place.

FIGURE 1

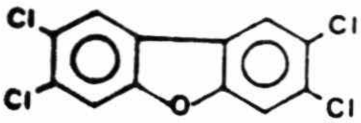
| | |
|---|---|
| Formula | $C_{10}H_{10-x-y}Cl_{x+y}$, $1<x+y<10$ |
| Structure |  |
| No. of isomers | 209 |
| Dielectric Constant | High |
| Thermal Properties | - thermally stable<br>- high thermal conductivity |
| Chemical Properties | - oxidation slow<br>- low volatility<br>- resists acid and base attack<br>- non-flammable<br>- lipophilic $K_{oct}/H_2O$ $3 \times 10^5$ |
| Biological Properties | - low acute toxicity<br>- bioaccumulative<br>- weak carcinogenisis suspected<br>- induces chloracne, reproductive failure, pyrophoria, wasting |



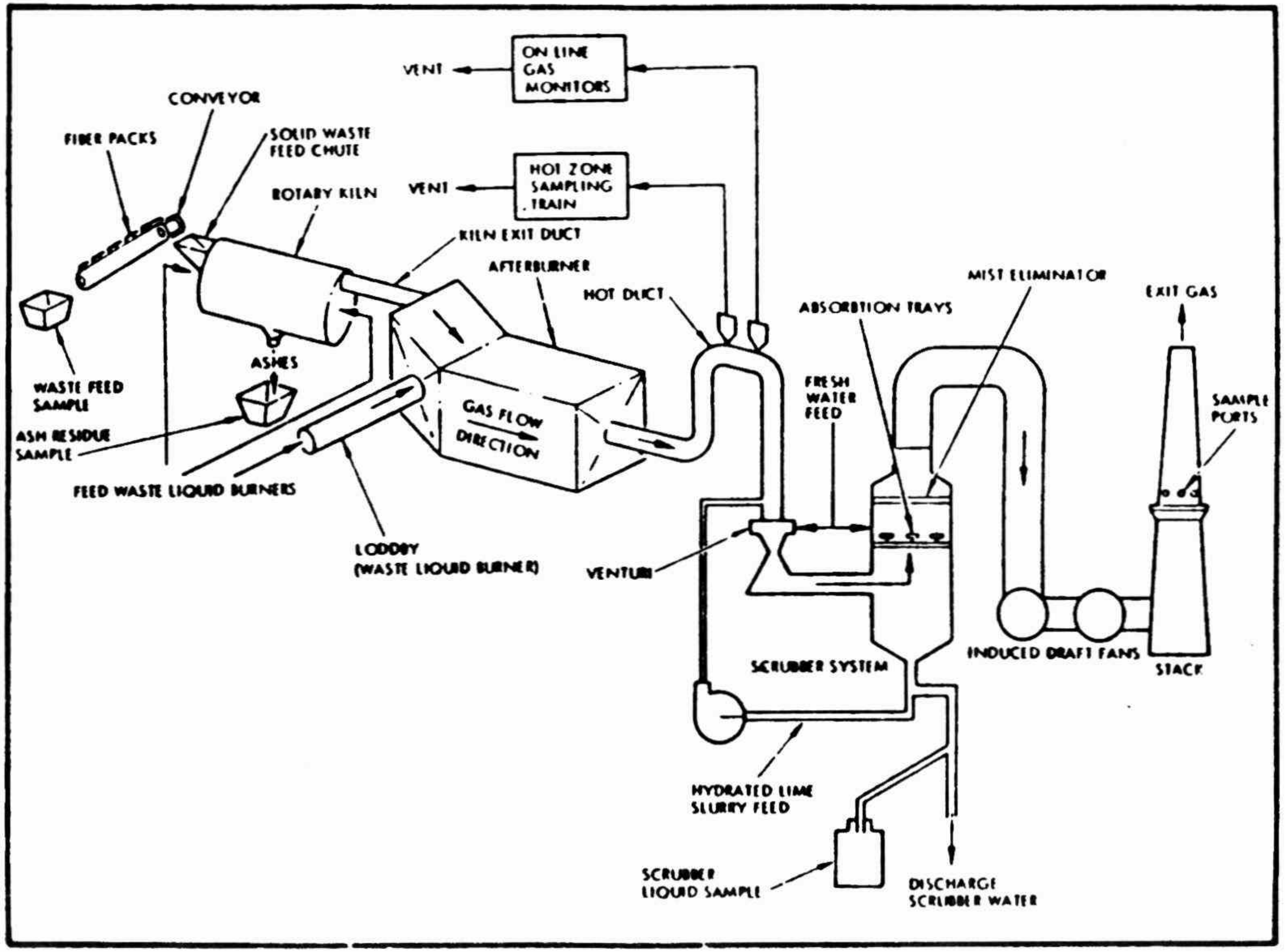
tetrachlorobiphenyl



tetrachlorodibenzo-para-dioxin



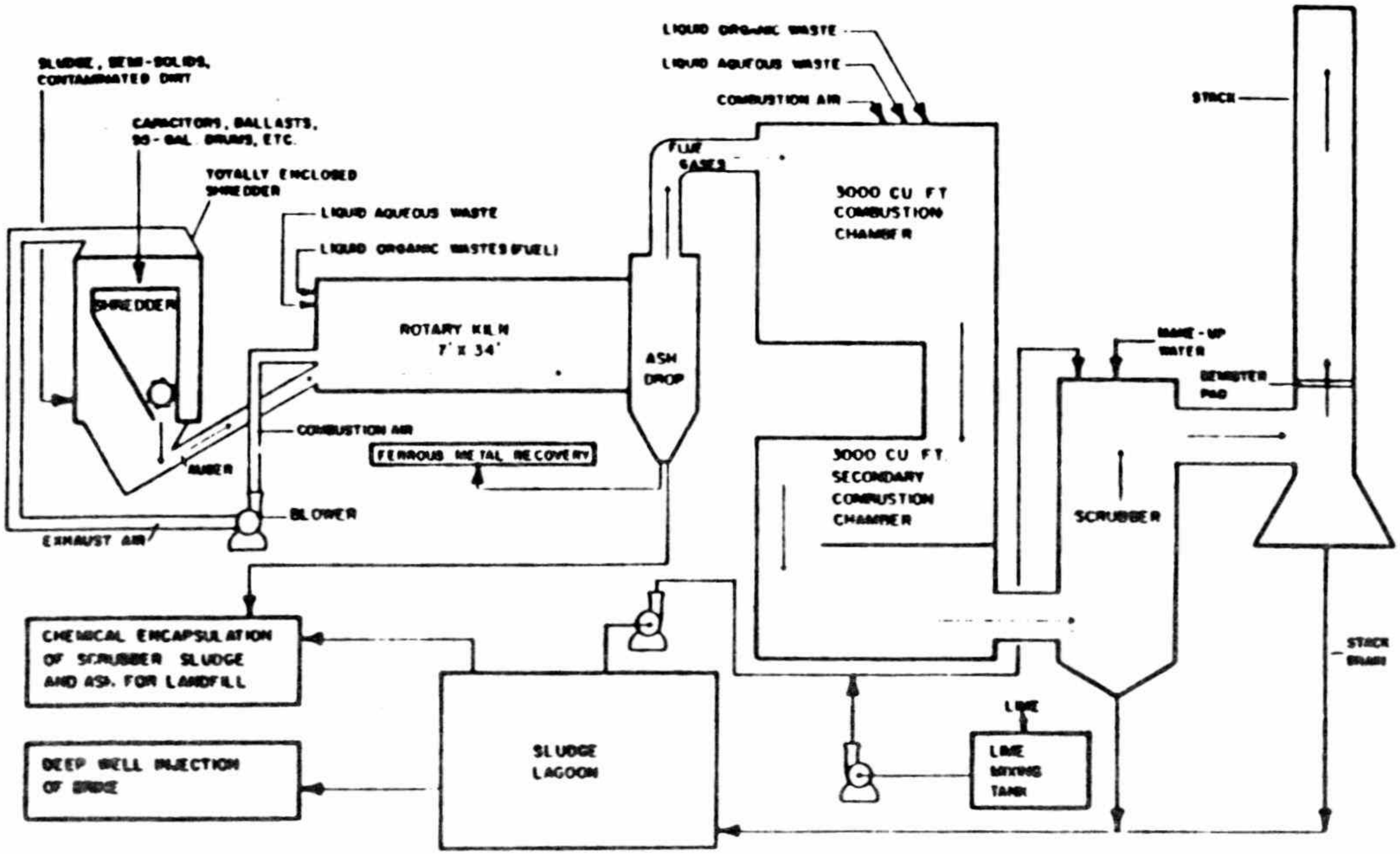
tetrachlorodibenzofuran



Schematic of Rollins Environmental Services' Incinerator

Reproduced from Disposal of PCBs and PCB Contaminated Materials, Electric Power Research Institute, October 1979.

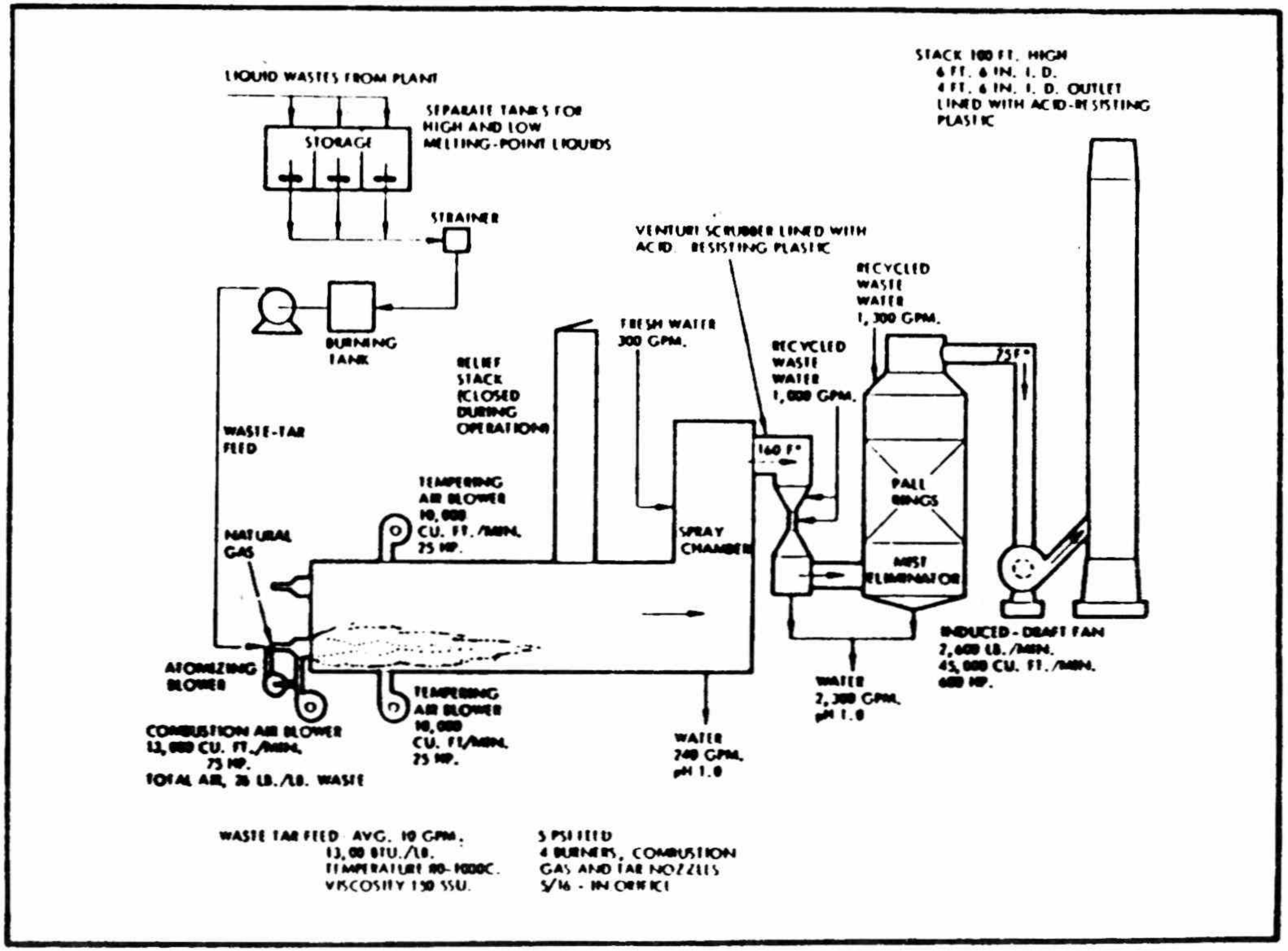
FIGURE 3


SLUDGE, SEMI-SOLIDS, CONTAMINATED DIRT
CAPACITORS, BALLASTS, 55-GAL DRUMS, ETC.
TOTALLY ENCLOSED SHREDDER
SHREDDER
AUGER
EXHAUST AIR
BLOWER
COMBUSTION AIR
LIQUID AQUEOUS WASTE
LIQUID ORGANIC WASTES (FUEL)
ROTARY KILN 7' x 34'
FERROUS METAL RECOVERY
ASH DROP
FLUE GASES
LIQUID ORGANIC WASTE
LIQUID AQUEOUS WASTE
COMBUSTION AIR
3000 CU FT COMBUSTION CHAMBER
3000 CU FT SECONDARY COMBUSTION CHAMBER
MAKE-UP WATER
DEMISTER PAD
STACK
SCRUBBER
STACK DRAIN
LIME
LIME MIXING TANK
SLUDGE LAGOON
CHEMICAL ENCAPSULATION OF SCRUBBER SLUDGE AND ASH FOR LANDFILL
DEEP WELL INJECTION OF BRINE

Schematic of ENSCO Incineration System

Reproduced from Company Literature.

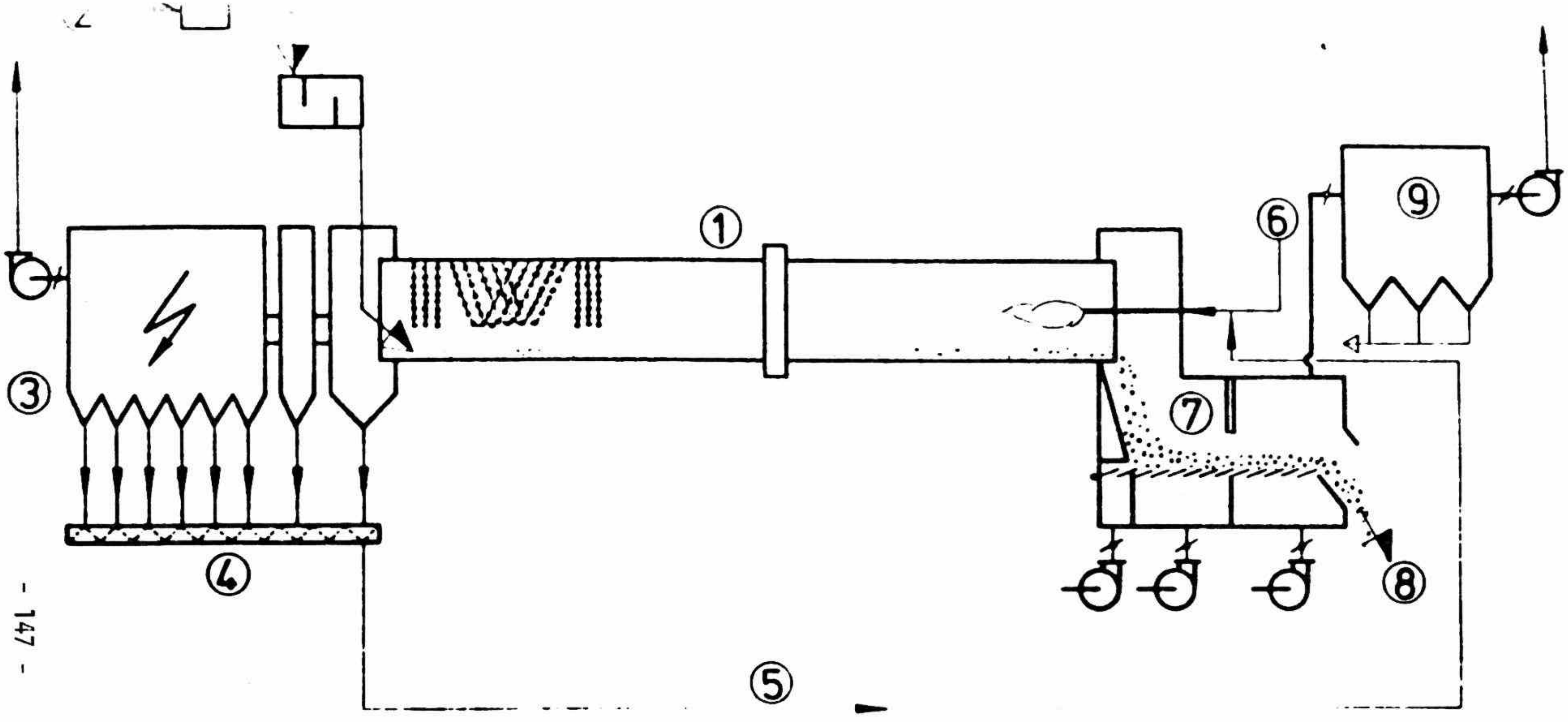
FIGURE 4


LIQUID WASTES FROM PLANT
STORAGE
SEPARATE TANKS FOR HIGH AND LOW MELTING-POINT LIQUIDS
STRAINER
BURNING TANK
WASTE-TAR FEED
RELIEF STACK (CLOSED DURING OPERATION)
FRESH WATER 300 GPM.
VENTURI SCRUBBER LINED WITH ACID RESISTING PLASTIC
RECYCLED WASTE WATER 1,300 GPM.
RECYCLED WASTE WATER 1,000 GPM.
STACK 100 FT. HIGH
6 FT. 6 IN. I. D.
4 FT. 6 IN. I. D. OUTLET
LINED WITH ACID-RESISTING PLASTIC
75 F°
160 F°
PALL RINGS
MIST ELIMINATOR
SPRAY CHAMBER
TEMPERING AIR BLOWER 10,000 CU. FT./MIN. 25 HP.
NATURAL GAS
ATOMIZING BLOWER
COMBUSTION AIR BLOWER 13,000 CU. FT./MIN. 75 HP.
TOTAL AIR, 26 LB./LB. WASTE
TEMPERING AIR BLOWER 10,000 CU. FT/MIN. 25 HP.
WATER 240 GPM. pH 1.0
WATER 2,300 GPM. pH 1.0
INDUCED-DRAFT FAN 2,600 LB./MIN. 45,000 CU. FT./MIN. 600 HP.
WASTE TAR FEED AVG. 10 GPM.
13,00 BTU./LB.
TEMPERATURE 80-1000C.
VISCOSITY 150 SSU.
5 PSI FEED
4 BURNERS, COMBUSTION GAS AND TAR NOZZLES
5/16 - IN ORIFICE

Horizontally Fired Liquid Waste Incineration System

Reproduced from Disposal of PCBs and PCB Contaminated Materials, Electric Power Research Institute (EPRI), October 1979.

FIGURE 5



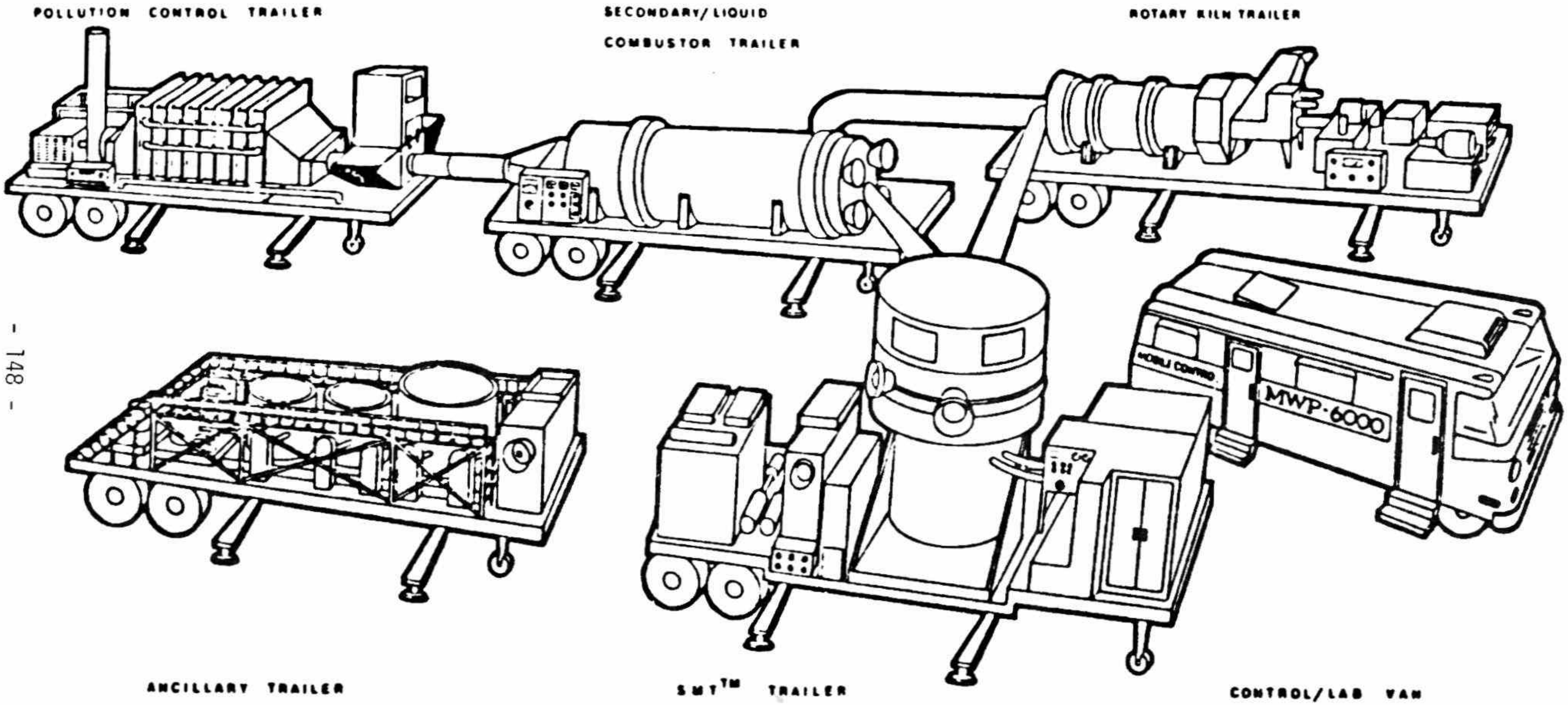
1 - KILN
2 - SLURRY FEED
4 - PRECIPITATOR DUST SCREW
3 - PRECIPITATOR
5 - DUST RETURN

6 - FUEL
7 - CLINKER COOLER
8 - CLINKER
9 - FILTER

WET PROCESS KILN

Reproduced from Company Literature.

FIGURE 6



MOBILE HAZARDOUS WASTE PROCESSOR

Reproduced from Company Literature.

# PREPARATION OF OPERATION AND MAINTENANCE PLANS FOR FACILITIES THAT GENERATE, STORE, TREAT AND DISPOSE OF HAZARDOUS WASTES

By

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## INTRODUCTION

It has been often stated that any process which is utilized to treat and/or dispose of hazardous waste is only as good as the manner in which it is operated and maintained. Even in the generation, handling, and collection of these wastes in the generator's plant, certain operating plans serve to organize the company's efforts to better manage these wastes and prevent problems from occurring.

In the United States, formal operating plans are required by the Resource Conservation and Recovery Act for any company that treats, stores, or disposes of hazardous wastes. A variety of other hazardous materials regulations also have certain requirements for formalized plans. Compliance with the regulations place great economic and operational demands on these companies - complete with potential enforcement penalties and intense public scrutiny. Regulations also exert considerable pressure on individual managers and corporations to develop new and effective approaches, management practices, policies and procedures, plans, commercial practices, and employee training.

Many companies now are beginning to realize the benefits which accrue from having these plans in their own operation. These benefits include:

- improved safety records with insurance savings and increased employee morale.
- company public image protection.
- avoidance of citations, penalties, and mediation costs.
- minimize costs of regulatory compliance.

From a risk avoidance point of view, these plans should help the company with early minimization of liability including environmental damage or injury to human health. They also provide early maximization of control of liability.

The purpose of this paper is to briefly show what plans should be considered for a facility and what their major components should be. No attempt has been made here to cover every possible item or to be specific to United States regulations. A common sense approach to the development and use of these plans should always be the rule.

## WASTE ANALYSIS PLAN

Facilities which generate or manage hazardous wastes need to know certain information about these materials in order to handle them safely and to comply with regulatory reporting requirements. A waste analysis plan which is appropriate to the waste that is handled and the type of facility should be prepared and followed. Without such a plan, many waste generators know very little about their waste properties. Careful watch should be maintained for changes in the process or operation generating the waste to see if its properties or characteristics are altered.

The waste analysis plan describes the parameters for which each waste type will be analyzed. Also included should be the specific analytical procedures used, sampling method to insure representative samples, and the testing frequency. If the waste management facility is removed from the waste generation location (i.e., off-site), specific procedures should be used to insure that the wastes received at the facility match the wastes designated on the manifest (i.e., waybill) and match the wastes for which the facility is capable or approved to manage. Some level of creativity can be used by a skillful analytical chemist to minimize the costs while maximizing the benefits of such a program. This particular plan provides the facility with much information on the manner in which it should operate and the strictness of the items in the plans described below. It is also the plan which is most frequently disregarded when establishing and implementing operation and maintenance procedures.

## SECURITY PLAN

Facilities generating or managing hazardous wastes should have a written plan to prevent unknowing entry of people and minimize the potential for unauthorized entry of people or animals onto the active portions of the facility. This can be accomplished by a number of means including: a 24-hour surveillance system, an artificial or natural barrier surrounding the facility, or other means of controlled entry to the area. In all cases, signs with a legend such as "Danger - Unauthorized Personnel Keep Out" should be utilized. The signs should be in the predominant languages and posted to be seen from any approach and legible from a suitable distance (e.g., 25 feet in the United States).

As with other plans, the security plan should be in writing and must be kept current with changes in the facility. Other plans such as the inspection plan are designed to make certain that the components of this plan are intact over time.

## GENERAL INSPECTION PLAN

It is most important that the facility be inspected for malfunctions and deterioration, operator errors, and damages which may be causing or lead to the release of hazardous waste constituents to the environment. A written inspection plan must be developed and followed on a fixed schedule. This will be based on a facility's critical processes, equipment, and structures and on the potential for failure and the rate of any deterioration processes (e.g., corrosion, erosion, etc.) which may lead to failure. The plan must contain provisions to remedy any defects noted in the inspections. These inspections must be conducted often enough to identify potential problems in time to correct them before they can create problems. The plan should identify the specific types of problems which should be looked for (e.g., inoperative sump pump, leaking fitting, eroding dike, etc.). A record should be kept of all inspections including when made, who made it, and note when repairs were made. A simple log book can be used for this record. Security personnel can be trained to make many of the more frequent inspection items.

Inspection plans provide some incidental benefits to the facility. The records will assist management in auditing the reliability of certain equipment, the efficiency of maintenance activities, and the effectiveness of the inspection schedule. All of these items are important in risk and loss avoidance programs. Should an incident actually occur, records will help to reconstruct the events that led up to it and may also provide a valuable resource for any emergency decisions that may be required.

Because of the importance of this plan to a facility, some further examples of what could be included are provided below:

- storage areas - look for rust, corrosion, cracks, missing or improper labels, spills.
- dikes - look for damage, structural weakening, examine drainage system for stoppage.
- operating and monitoring equipment - check for normal operations and readings.
- safety and emergency response equipment - check that it meets requirements.
- security devices - check for damages.
- vegetation on and around facility - check for damage.
- active portion of facility - check for fugitive air emissions and odors.
- records - record results of inspection in daily operating record.

Information on the operating record is described later in this paper.

## PREPAREDNESS AND PREVENTION PLAN

When dealing with hazardous wastes, facilities should be designed, constructed, maintained, and operated to minimize the possibility of a fire, explosion, or any unplanned sudden or gradual release of hazardous constituents to the environment. This plan is often included in the contingency plan. However, it is separated here to emphasize its importance in helping to prevent contingencies.

The facility should be equipped with an internal communications system (e.g., alarms, telephones, hand-held two-way radios) capable of providing immediate emergency instructions to facility personnel. Immediate access to this equipment by employees is also important in case they need to summons emergency assistance.

Portable fire extinguishers, fire control equipment, spill control and decontamination equipment, water at adequate volume and pressure, foam producing equipment, and automatic sprinklers should be provided if necessary with proper testing, inspection, and maintenance to assure it will work properly in time of emergency. Aisle space in the facility must remain unobstructed to allow for movement of personnel, fire protection equipment, spill control and decontamination equipment to any area during an emergency.

Prior arrangements should be planned to familiarize police, fire departments, and emergency response teams with the layout of the facility, properties of the hazardous waste handled at the facility and any special associated hazards posed by the operation.

The planning should invovle the formulation of any conceivable scenarios which would lead to the need for contingency and emergency actions followed by a description of what should be done. These items are discussed further in the plan below.

## CONTINGENCY AND EMERGENCY RESPONSE PLAN

A contingency plan for a hazardous waste generator or management facility must be designed in an effort to minimize hazards to human health and the environment in the event of fire, explosion, or any accidental release of hazardous waste to the air, soil, or surface water. This contingency plan should include the following information:

- the responsibilities of the facility's emergency coordinators.
- definitions of what constitutes an emergency and a description of the planned response to any emergencies at the facility.
- a list of the facility's emergency coordinators.
- an evacuation plan.

This plan should be kept up-to-date with amendments and revisions made when potential for discharge of hazardous waste change due to change in facility design, construction, or maintenance. Other reasons for change include: changes in emergency personnel or equipment or post-incident studies which recommend changes.

The emergency coordinator designation is a most important element in the plan. A coordinator must be present whenever the facility is in operation. This person must be familiar with the operation and must be specifically listed with name and address in the plan. Among the duties of the emergency coordinator are the following:

- activate on-scene alarms.
- notify appropriate emergency agencies as necessary.

- notify local authorities if evacuation of local areas seems necesary.

- in case of discharge, identify the discharged material as to quantity, character, source, and extent by using records, manifests, and chemical analysis, as appropriate.

- cooperate with authorities.

- provide for disposition of recovered wastes, contaminated soil or material resulting from the emergency.

- insure no waste incompatible with the released material is handled until the emergency is over.

- subsequent to shutdown, check pipelines and other equipment for leaks, pressure buildup, rupture, etc.

- insure all emergency equipment is restored to preincident condition.

Other duties are assigned to this individual as appropriate.

An evacuation plan should be incorporated into this document. It should outline likely evacuation routes together with alternate routes. Also included should be the signal which will be used to mark the beginning of the evacuation.

Local fire and police departments, hospitals, ambulance services, government officials, and the facility's emergency coordinators and staff should all have copies of the contingency plan for reference in case of any emergency. This plan will offer each agency:

- a full understanding of the emergency response program.

- the understanding of their role in the program.

- detailed information regarding the facility and its emergency response capabilities.

- assistance in the training of individual agencies' personnel in terms of studying the layout of specific facilities and determining special requirements needed (e.g., chemical spill/fire handling, special equipment handling, etc.).

## PERSONNEL TRAINING PLAN

The purpose of this plan is to reduce the potential for mistakes which might threaten human health or the environment by ensuring that facility personnel acquire expertise in the areas to which they are assigned. In order to function properly, personnel who work at hazardous waste management facilities or who drive equipment destined for such facilities, must successfully complete a program of classroom instruction or on-the-job training. This program should be directed by a person suitably trained in hazardous waste management procedures (including contingency plan implementation) relevant to the positions in which they are employed.

At a minimum, the training program is designed to ensure that facility personnel are able to respond effectively to emergencies by familiarizing them with emergency procedures, emergency equipment and emergency systems. Where applicable, the following items are included:

- procedures for using, inspecting, repairing, and replacing facility emergency and monitoring equipment.
- key parameters for automatic feed cut-off systems.
- communications or alarm systems.
- response to fires or explosions.
- response to groundwater contamination incidents.
- shutdown of operations.

Ideally, the training program is extended to include both preparedness and prevention planning considerations to keep emergencies from happening.

Another aspect of the training plan requires the facility operator to provide each employee who works with hazardous waste a job title and a written job description. Records must be kept with this information and documentation of the training received by each individual. Employees must not work in unsupervised positions until they have completed their training program. All facility personnel must take part in an annual review of their training. Records must be kept for these updates or whenever a person is given a new position at the facility which requires modification in the training needs. Training records on current personnel should be kept until closure of the facility. Training records for former employees need to be retained for at least three years from the employee's termination date.

The training plan is broken down by facility components. Each component, while retaining many similar training program elements, has its own unique considerations. Because many employees will work within a limited number of facility components, training needs are assessed and implemented in this manner.

## RECORDKEEPING PLAN

Various regulations and the spector of liability claims make it imperative that a plan be written to designate which records should be maintained and how long they should be retained. Manifest documents must be properly filled out and tracked. A program to retain them for three or more years is advisable. Training records generated from the plan described above must also be kept.

One of the most important parts of this plan is a written operating record. This record should contain the following:

- a description and quantity of hazardous waste generated/received.
- method of treatment, storage, or disposal.
- location and quantity of each hazardous waste.
- records and results of waste analysis.
- summary reports.
- details of all incidents that required implementing the contingency plan.
- records and results of inspections.
- any monitoring, testing, or analytical data should also be included in the operating record.

Recordkeeping formats should be simple and compact to insure that they will be utilized effectively and can be stored for the period required.

## GROUNDWATER AND LEACHATE MONITORING PLAN

Facilities which have landfills or surface impoundments must have a groundwater and leachate monitoring plan. It is also available for facilities which have a high susceptibility to spillage or runoff from piles. This plan must be capable of determining the impact on the quality of groundwater in the uppermost aquifer underlying the facility.

The plan should specify the groundwater monitoring system specifications including the number and location of the wells together with details on well construction. Attention must be given to the determination of background (upgradient) water quality conditions.

When applicable, leachate monitoring should be conducted in the zone of aeration immediately beneath the facility and above the top of the water table. This will provide an early warning system.

A sampling and analysis program should be designated which identifies sampling frequency, collection method, preservation and shipment of samples, chain-of-custody procedures, minimum parameters and analytical methods to be utilized, and the level of recordkeeping required.

Facilities should seek the services of a competent hydrogeologist and environmental analytical chemist to help with the formulation of this important plan. Reliance on well drillers and plant chemists may lead to problems in the implementation and defensibility of this plan.

## CLOSURE AND POSTCLOSURE CARE PLAN

A closure plan describes how the facility will be closed; a description of possible uses after closure; and the anticipated time before the close-out, estimated time for closure and anticipated partial closures. In all cases, proper closure should minimize the need for further maintenance and controls. Closure must be completed within a specified time period after activity stoppage. All equipment should be disposed or decontaminated. The facility should be secured during closure to insure that humans and animals cannot come in contact with hazardous wastes and so discharges cannot occur. Even before closure is anticipated, a cost estimate should be prepared and assurance of closure should be provided. In every case, certification by a knowledgeable registered engineer should be obtained that the facility has been properly closed.

Postclosure care is required when wastes remain on the site after closure. A program for monitoring and reporting must be established. Maintenance of security and containment devices must be provided. If ownership is transferred, the new owners must comply with the plan. As in the case of the closure plan, the facility must assure that it can bear these costs.

# An Approach to Low Level Radioactive Waste Management

by

Alun W. James,
Head, Radioactivity Unit,
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Environment Ontario, Toronto.

Some of you may be wondering why anyone from the Provincial Government would be speaking on the management of low-level radioactive waste - isn't that a Federal Government matter?

The Ministry of the Environment has traditionally taken the position that anything to do with low-level radioactive waste does come under Federal jurisdiction. The fact that I have been asked to speak here today doesn't mean that there has been a change in that position - but it does indicate that the Ministry is concerned about the problems of low-level radioactive waste.

I'm afraid I won't be able to offer any easy solutions to these problems. What I will attempt to do is to give an overview of some of the Ministry's concerns and a summary of current work and future plans.

The first slide shows the six topics covered by this talk:

(Slide #1: Contents of Talk)

The sources of low-level radioactive waste in Ontario can be divided into four categories as shown in the next slide.

(Slide #2: Sources of LLRW)

(Slide #3: Definition of 'Incidental' LLRW)

About a year ago, the Federal Government commissioned Hickling - Partners Incorporated to put forward proposals regarding which agency should be responsible for the various sources of low-level radioactive waste and to recommend the management structure. The division of responsibility suggested by the Hickling - Partners' report is shown in the following slides:

(Slide No. 4: Proposed Primary Responsibilities for both Normal and Historic Wastes).

(Slide No. 5: Proposed Ultimate Responsibility for both Normal and Historic Wastes).

It should be pointed out that the divisions of responsibility proposed in the Hickling report are the subject of on-going negotiations between the Federal and Provincial Governments. But even though Ontario's role in low-level waste management has not yet been agreed upon, the Province has already had some involvement in a number of LLRW problems - most notably the following:

(Slide No. 6: Recent Problem Areas Concerning LLRW).

I shall spend some time now describing the problems with the wastes from abrasive manufacturing industry because these epitomize some of the difficulties to be faced with the management of LLRW.

The Norton Company in Niagara Falls and the Exolon Company in Thorold manufacture abrasive products. In one of its processes, the Norton Company uses imported Baddeleyite sands - Exolon has, in the past, also used this sand. The Baddeleyite contains naturally occurring uranium, thorium, and radium in concentrations significantly greater than are normal for soils in Southern Ontario.

The waste material from the use of the Baddeleyite also contains elevated concentrations of these radionuclides. This waste was formerly taken to a privately owned landfill site. Both the Atomic Energy Control Board and the Radiation Protection Service of the Provincial Ministry of Health considered this to be a suitable disposal method. However, in 1980 the Regional Staff of the Ministry of the Environment were asked to review the wastes which went into the landfill site - the owners had decided that they would only accept wastes which could be defined by the Ministry of the Environment as being "Non-Hazardous".

Regulation 309 of the Environmental Protection Act defines hazardous waste as follows:

(Slide.No. 7: Regulation 309 Under the Environmental Protection Act. Definition of "Hazardous Waste").

As shown, radioactive waste is defined as being hazardous waste. But all materials on the earth's surface contain some radioactivity either from naturally occurring radionuclides or from fallout from nuclear weapons testing. Thus, according to the regulations, all materials could be looked upon as being hazardous due to their low concentrations of radioactivity. As a practical guideline, materials may be considered radioactive only if their concentration of radionuclides is greater than the concentration present in local soil. But even with this definition of radioactivity, the wastes from the use of Baddeleyite sand must still be considered radioactive and therefore hazardous. Now "hazardous" materials cannot be disposed of in landfill sites unless the site has a Special Certificate of Approval to accept that waste. This special certificate can only be obtained after public hearings, or, in emergency cases, by Cabinet Directive. The owners of the private landfill site did not want to go through the rigours of a public hearing so they declined from asking the Ministry of the Environment for a Special Certificate of Approval to receive the Baddeleyite waste.

In October 1980, therefore, the Ministry told the Norton Company to store the waste from use of the Baddeleyite sand on site until a disposal system has been developed. Exolon Company was no longer using Baddeleyite on a routine basis but did have some of the waste already stored on site. Norton Company has continued to use Baddeleyite sand in one of its processes, storing the waste in silos on site.

But there is some good news: The Norton Company is presently installing a process which will be able to make pellets of the stored waste which can then be re-introduced into the manufacturing process. This will considerably reduce the volume of waste which must be stored on site. But some wastes will remain and will have to be disposed of sometime. Which leads me to the next point I want to discuss - the appropriate means of the disposal of low-level radioactive waste.

The degree to which a low-level radioactive waste should be isolated from the public realm should depend on the potential radiological hazard of the waste. As an initial attempt to determine the appropriate disposal means for a particular LLRW, it may be desirable to categorize the waste into one of three types depending on its radiological characteristics. These characteristics would include such things as leachability, radiation emissions, specific activity, radon generating capacity, half-life, etc.

The next few slides give rough definitions of these three types.

(Slides Nos. 8, 9 and 10, Proposed types of Radioactive Waste).

I stress that these are only qualitative proposals and no quantitative differentiation has yet been made between the three types of low-level waste, nor between "type 3" wastes and "intermediate level" wastes. But as a real-life example of the need for these three types, I will return to the waste from the abrasive manufacturing industry discussed earlier:

In the fall of 1981 some stored waste material was taken from the Exolon property and used as landfill for a commercial building. When the local office of the Ministry found out about this use, they took samples of the fill material and had them analyzed at the Ministry of Labour's Radiation Protection Laboratory. The fill was found to have slightly elevated concentrations of radium and thorium.

But the material was not waste from the use of Baddeleyite - it was from the use of ordinary Bauxite, and Bauxite, too, has concentrations of radionuclides slightly higher than is present in some soils in Southern Ontario.

We thus had to address three problems:

1. Could the waste material remain as fill for the commercial building?

2. If so, could the Bauxite waste be defined as "type 1" waste so that anyone could use it as fill? and

3. If the Bauxite waste has now to be considered "radioactive" can it still be disposed of in landfill sites?

The Ministry consulted with the AECB and the Ministry of Labour on these questions. In the spring of this year the MOL undertook radiation monitoring in the building. (Slide 11: Radium-226 decay chain). These tests showed that the radon daughter concentration in the building was only 0.006 working levels (WL), which is considerably below the 0.02 WL guideline for areas where the Federal Government has undertaken remedial clean-up measures.

So the owner was advised that there was no problem as of now, but that future tests would be undertaken.

Does the fact that the radon daughter levels were low mean that the waste can be categorized as type 1 waste? i.e. can the Bauxite waste be used for building purposes? The answer is - we still don't know. It is still possible that if the building put up over the fill had had poor ventilation, the radon daughter levels may have been significant.

The other question is "if the Bauxite contains any radioactivity above normal levels, should it be considered hazardous?" Our answer to this has been pragmatic. The radionuclide concentration in the waste is only marginally above the concentration of radionuclides in some clays found in the area. Also, laboratory tests showed that the radionuclides in the Bauxite waste did not readily leach out under a range of pH conditions. So it has been decided that, for the time being at least, waste from use of ordinary Bauxite should not be considered a hazard and can therefore go to sanitary landfill sites.

However, Baddeleyite waste and some other industrial wastes in the Province present a greater problem - these may have radionuclide concentrations ten times the average concentration in soils in the general area. So how can we deal with these LLRW's? What we need to do is to assign quantitative parameters to the three types of waste described earlier - we need to know which wastes, if any, can be used for building purposes; which wastes, if any, can go to local landfill sites, and which have to remain in storage until a special LLRW repository has been developed.

It is generally accepted - e.g. by the International Atomic Energy Agency - that the best way to determine the appropriateness of a disposal practice is to estimate the radiation dose which a member of the public would receive as a result of the practice. There are a number of pathways by which disposed waste could expose a member of the public.

(Slide No. 12: Pathways of Exposure)

As you are aware we are all continually exposed to radiation from cosmic rays and from naturally occurring radionuclides in the ground, in building materials, in our bodies and the bodies of people close to us. The average Canadian is exposed to about 100 millirem per year - not counting medical or occupational exposure.

(Slide No. 13: Unit of Radiation Dose Equivalent)

But how do we handle doses other than those from nature?

A system of limiting additional dose has been recommended by the International Commission on Radiological Protection, the main features of which are as follows:

(Slide No. 14: ICRP Recommendation on Dose Limitation)

These recommendations can be summarized as a need for justification, optimization and compliance.

The dose equivalent limit to an occupationally exposed worker is 5000 millirem per year. The dose equivalent limit to a member of the public as a result of a nuclear facility is 500 millirem per year.

So 500 millirem per year represents a maximum permissible individual dose rate. Is there also a dose rate so low that it can be ignored from a regulatory viewpoint?

Theoretically, any radiation dose no matter how small gives rise to the possibility of cancer induction. But the risk of the cancer induction decreases as the degree of the exposure decreases. The ICRP assumes that if one million people were exposed to one rem each, the excess cancer incidence would be about 100. So the risk from one rem is about one in ten thousand. Therefore the risk from one millirem per year is about one in ten million per year, ($10^{-7}$/yr). This is a risk which most members of society will ignore in day to day living. But even if one in ten million is an insignificant risk, does that mean that one millirem a year is an insignificant dose rate?

AECB staff are currently wrestling with the problem of what radiation dose rate might be considered insignificant from a regulatory standpoint. One of their tentative suggestions - based in part on draft recommendations of the International Atomic Energy Agency - is shown in the next slide:

(Slide No. 15: AECB Staff's Tentative Recommendation on "Insignificant" Dose Rate to Individual Members of the Public)

When the AECB has better clarified its position on the question of insignificant dose, it will issue a consultative document to obtain input from other interested parties - including the public.

Staff of the Ministry of the Environment are anxiously awaiting this development; we think that the definition of an insignificant dose rate may be very helpful in our attempt to find a suitable disposal means for low-level radioactive waste. If it could be shown theoretically that a low-level waste from naturally occurring materials would give rise to an individual dose rate of less than the insignificant dose rate once it had been disposed of in a landfill site, then the radiological impact of the disposal practice may be disregarded. (The estimated dose rate to the individual would have to include possible exposure from all pathways and from all LLRW in the landfill site).

But what if the theoretical dose rate from the disposal of the waste were slightly greater than the insignificant value, by say five or ten millirem per year? Might this low dose rate, though not "insignificant", still be acceptable? And - a crucial question - who is to decide whether it is acceptable - the Federal Government, the Provincial Government, or the local community?

But such decisions will not have to be made for some time yet, we first have to learn more about the pathways by which members of the public can be exposed to disposed wastes and how best to estimate the dose-rate from these pathways. Also, we must continue to work with the Federal Government to help develop a facility specifically for the disposal of low-level radioactive waste.

These and related issues will, no doubt, continue to present technical and political challenges for both the Federal and Provincial Governments.

SLIDE #1

# AN APPROACH TO LLRW MANAGEMENT

- Sources
- Proposed division of responsibility
- Provincial involvements
- Disposal options
- Exposure pathways
- 'Insignificant' dose rate.

SLIDE #2

## SOURCES OF LLRW

THE NUCLEAR FUEL CYCLE

HISTORIC RADIUM OPERATIONS

USE OF RADIOISOTOPES

'INCIDENTAL LLRW'

SLIDE #3

## 'INCIDENTAL LLRW'

CONTAIN RADIONUCLIDES WHICH ARE

- NATURALLY OCCURRING
- OF NO USE IN PROCESS OR USEFUL CHEMICALLY (NOT RADIOLOGICALLY)

SLIDE #4

PROPOSED PRIMARY RESPONSIBILITIES

| | NUCLEAR CYCLE | AECL | USERS OF RADIOISOTOPES | INCIDENTAL AGENT OF PROVINCE |
|---|---|---|---|---|
| REGULATION | AECB | AECB | AECB | |
| HANDLING & STORAGE | USER | AECL | USER | USER |
| DISPOSAL | USER | AECL | USER | USER |
| FINANCIAL | USER | AECL | USER | USER |

## SLIDE #5

PROPOSED ULTIMATE RESPONSIBILITIES

<table>
<tr><th></th><th>NUCLEAR CYCLE</th><th>AECL</th><th>USERS OF RADIOISOTOPES</th><th>INCIDENTAL</th><th>NATURAL OCCURRENCE</th></tr>
<tr><td>REGULATION</td><td colspan="3" rowspan="4">FEDERAL</td><td colspan="2" rowspan="4">PROVINCIAL</td></tr>
<tr><td>HANDLING & STORAGE</td></tr>
<tr><td>DISPOSAL</td></tr>
<tr><td>FINANCIAL</td></tr>
</table>

SLIDE #6

# RECENT PROBLEM AREAS

MALVERN SUBDIVISION

HISTORIC RADIUM-DIAL FACTORIES

ABRASIVE MANUFACTURING INDUSTRIES

PHOSPHATE INDUSTRY

SLIDE #6

MALVERN

I expect that most of you have heard about the low-level radioactive waste in the Malvern subdivision of Scarborough. This waste dates back to the 1940's; it originated at a radium dial-painting factory in Toronto and at a radium refinery at Port Hope. The waste was taken to what was then a farm in Scarborough for extraction of the radium and for research work. The farm was eventually sold and a subdivision built on the land. The soil in part of the subdivision is still contaminated as a result of the radium operations.

The Atomic Energy Control Board has tried to find a disposal site for this contaminated soil but has been restricted by public opposition and by a court-injunction which questioned AECB's authority to organize the management of low- level radioactive waste.

Since the court-injunction, the Provincial Government has been trying to resolve the situation with the help of the Scarborough and Toronto councils, but we haven't been very successful as yet.

SLIDE #6

## HISTORIC RADIUM-DIAL FACTORIES

One of these - on Davenport Road in Toronto - was in the news about 8 months ago. It was in operation during the 1940's. Staff of the AECB had checked the building a few years ago and had found some areas of contamination. They cautioned that precautions would be needed if any major renovations were undertaken due to the possible spread of this contamination. In the latter part of 1981, renovations were started but the AECB felt they were restricted from action by the court-injunction concerning the Malvern waste. So the Ministry of Labour undertook radiation monitoring and ensured that workers carrying out the renovation were protected from the contamination. The Ministry of the Environment issued a requirement that all contaminated waste had to be safely stored.

SLIDE #6

## PHOSPHATE INDUSTRY

The phosphate industry imports phosphate rock from Florida. This rock contains concentrations of naturally occurring radionuclides greater than are normal for soils in Southern Ontario. The AECB has never regulated this industry in Ontario.

The MOL has carried out on-site monitoring to ensure that the workers are adequately protected, and the MOE has, again, required that all contaminated wastes be safely stored on site.

SLIDE #7

## REGULATION 309 (FORMERLY 824) OF THE ENVIRONMENTAL PROTECTION ACT

"HAZARDOUS WASTE" MEANS WASTE THAT REQUIRES SPECIAL PRECAUTIONS IN ITS STORAGE, COLLECTION, TRANSPORTATION, TREATMENT OR DISPOSAL, TO PREVENT DAMAGE TO PERSONS OR PROPERTY AND INCLUDES EXPLOSIVE, FLAMMABLE, VOLATILE, RADIOACTIVE, TOXIC, AND PATHOLOGICAL WASTE.

SLIDE #8

## 'TYPE 1' WASTE

- RADIOLOGICALLY SIMILAR TO 'NORMAL' SOIL
- NEED NOT BE ISOLATED FROM PUBLIC
- CAN BE USED FOR BUILDING

SLIDE #9

# 'TYPE 2' WASTE

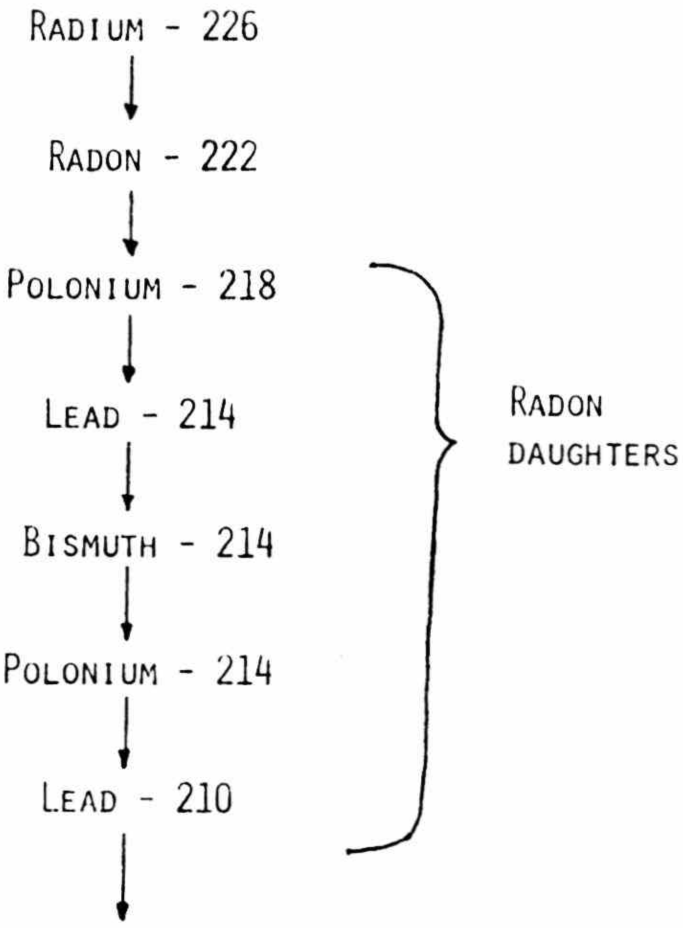
- UNCONTROLLED USE IMPRUDENT
- RADIOLOGICAL HAZARD NOT GREATER THAN HAZARD FROM WASTES DISPOSED OF IN LANDFILL

SLIDE #10

## 'TYPE 3' WASTE

NEEDS THE ISOLATION PROVIDED BY A SECURE LANDFILL SITE.

SLIDE #11



RADIUM - 226

↓

RADON - 222

↓

POLONIUM - 218

↓

LEAD - 214

↓

BISMUTH - 214

↓

POLONIUM - 214

↓

LEAD - 210

↓

RADON DAUGHTERS

SLIDE #12

# PATHWAYS OF EXPOSURE

- DIRECT GAMMA-EXPOSURE
- RADIONUCLIDES IN LEACHATE
- RADIONUCLIDES IN AIRBORNE DUST
- AIRBORNE RADON
- RADON IN GROUND WATER OR SOIL GAS
- RADIONUCLIDES IN FOOD CHAIN

SLIDE #13

## UNIT OF RADIATION DOSE EQUIVALENT: REM

TYPICAL DOSE RATE FROM NATURE: 100 MREM/YR

(NEW UNIT FOR DOSE EQUIVALENT: SIEVERT
1 Sv = 100 REM)

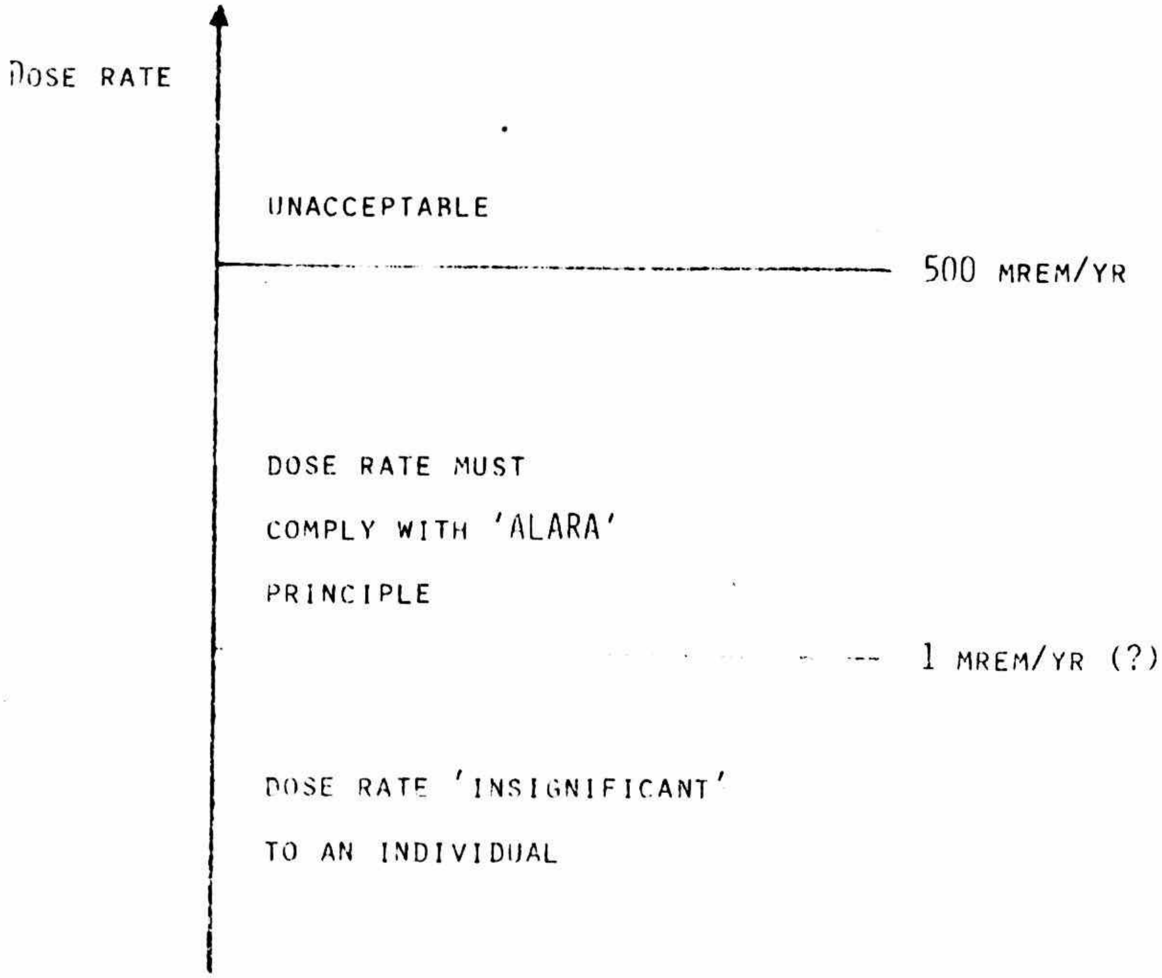
SLIDE #14

# DOSE LIMITATION

- POSITIVE NET BENEFIT
- ALL EXPOSURES SHALL BE ALARA
- DOSE EQUIVALENT SHALL NOT EXCEED ICRP LIMITS

SLIDE #15

## 'INSIGNIFICANT' DOSE RATE TO MEMBERS OF THE PUBLIC



DOSE RATE

UNACCEPTABLE

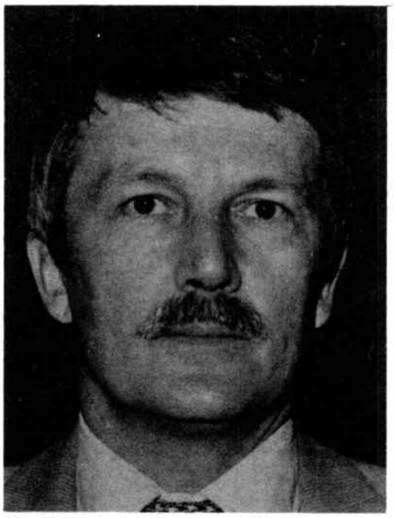
500 MREM/YR

DOSE RATE MUST
COMPLY WITH 'ALARA'
PRINCIPLE

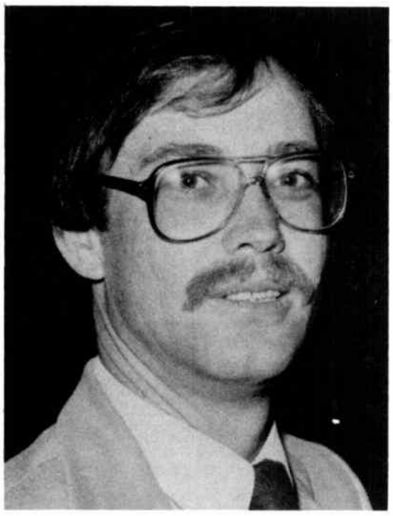
1 MREM/YR (?)

DOSE RATE 'INSIGNIFICANT'
TO AN INDIVIDUAL

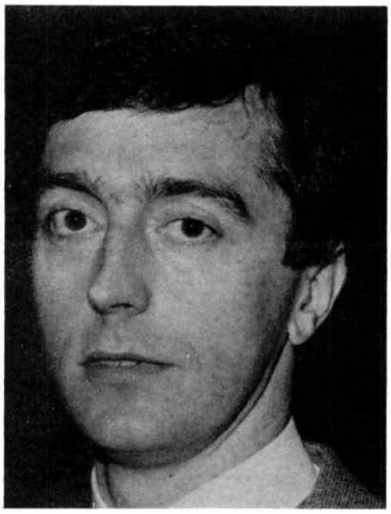
# SESSION IV - INDUSTRIAL WASTE MANAGEMENT - PART II



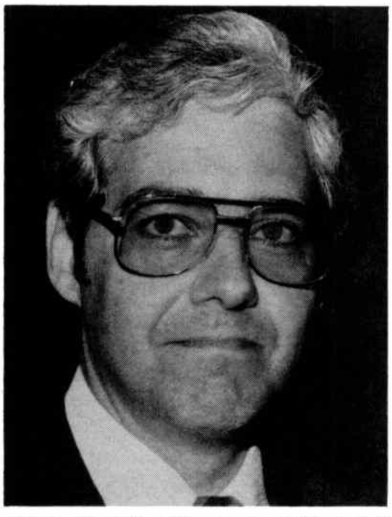
**Chairman:** G. Mierzynski
Acting Regional Director
Central Region
Ontario Ministry of the Environment
Don Mills, Ontario



S. G. Nutt,
Canviro Consultants Ltd.
Kitchener, Ontario



N. G. H. Guilford, Director
Tricil Ltd.
Mississauga, Ontario



Pierre Grenier, Operations Manager
Stablex (Canada) Limitée
Blainville, Quebec

R. Palombella
Department of Engineering
Regional Municipality of
Hamilton-Wentworth
Hamilton, Ontario

# AN INVENTORY OF LIQUID AND SPECIAL WASTES FOR THE REGIONAL MUNICIPALITY OF WATERLOO

By

S. G. Nutt and E. E. Shannon
CANVIRO Consultants Ltd.

Kitchener, Ontario

## Background and Program Objectives

The Regional Municipality of Waterloo is located in the central part of Southern Ontario, incorporating some 524 square miles of land and encompassing the Cities of Kitchener, Waterloo and Cambridge and the Townships of Woolwich, Wellesley, Wilmot and North Dumfries (Figure 1). The population of the Region is approximately 307,000. The industrial base in the Region is diverse with virtually all industrial sections, with the exception of tobacco, being represented. There are two large universities (University of Waterloo and Wilfred Laurier University) and one community college (Conestoga College) situated in the Region.

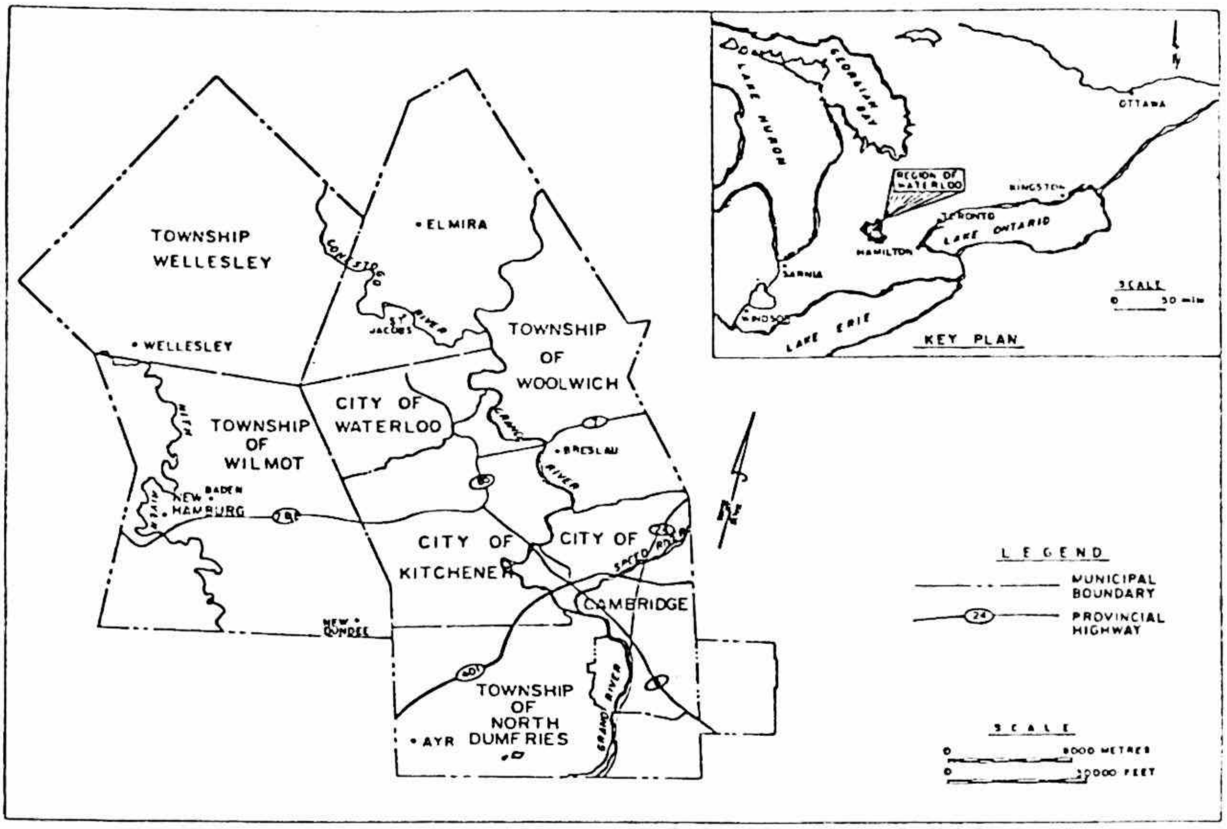


FIGURE 1 – REGIONAL MUNICIPALITY OF WATERLOO

In response to concerns expressed by Regional industries regarding the handling and disposal of liquid and special wastes, a program was initiated, aimed at providing solutions to the specific problems of industries and institutions within the Regional Municipality of Waterloo. Phase I in the development of such solutions involved identification and quantification of wastes generated within the Region through an inventory of industry, institutions and other selected commercial establishments. The specific objectives of the Regional inventory of liquid and special wastes were:

1. To determine the types, quantities and physical/chemical characteristics of wastes produced by each source.
2. To establish existing handling and disposal practices for these wastes.
3. To compile and collate the inventory data in a format compatible with the objectives of future phases.

The consultant team of CANVIRO CONSULTANTS LTD. and SIMCOE ENGINEERING LIMITED were awarded a contract to conduct the inventory and complete the data compilation. The program commenced in September 1981 with funding being provided by the Ministry of the Environment, the Kitchener Chamber of Commerce, the Department of the Environment and the Regional Municipality of Waterloo.

## Methodology

The first step in the inventory process involved the development of a "Master List" of industries, institutions and commercial establishments that were potential generators of liquid or special waste. Several data sources were utilized and cross-checked to compile the "Master List" as follows:

1. Listing of industries for sewer surcharge monitoring as contained in Region of Waterloo Engineering Department, Laboratory files.
2. Mailing lists from Regional Chambers of Commerce and Boards of Trade including Kitchener, Waterloo, Cambridge, Elmira-Woolwich, and New Hamburg.
3. Industrial listings for municipalities in the Region in "Scotts Industrial Directory for Ontario Manufacturing" 13th Edition, Penstock Directories Limited (1980).

In some cases the decision to include the particular industry on the "Master List" was based on the consultant's knowledge or prior experience with the company.

A questionnaire and coding format was developed specifically for this project. The coding system was necessary to provide a degree of confidentiality for the data and for subsequent computer analysis of the inventory data. In general, the questionnaire was designed to gather the following types of information on each waste generator:

1. Background Data
    - Standard Industrial Classification (SIC)
    - number of employees
    - water usage
    - wastewater treatment processes (if used)
    - type of sludge treatment

2. Liquid and Special Waste Data
    - general waste type
    - waste characteristics (contaminants, pH, % solids, etc.)
    - corrosivity, reactivity, toxicity and ignitibility information
    - storage method
    - storage time
    - present and future waste quantity
    - disposal method
    - waste hauler (if applicable)

In addition, provision was made for compiling other relevant information (process flow diagrams, etc) on the waste generator.

Industries, institutions and commercial establishments that were potential generators of liquid and special wastes were contacted initially via the appropriate Chamber of Commerce or Board of Trade. Subsequently, telephone contact was made by the Consultant and relevant data regarding the industry and any wastes generated were obtained by telephone or during an on-site interview depending on the complexity of the information. All interviewers were environmental engineers or technologists with specific experience and knowledge of industrial processes and wastewater treatment.

All of the questionnaire (telephone or on-site interview) data that had been compiled on the coding forms was entered onto a computer diskette (5 1/2" floppy disk) for subsequent microcomputer analysis. The computer system utilized for this project was an Apple system, comprising an Apple II 48K microcomputer with dual disk drives, and a MicroSoft Z80 Softcard. The system disk contains all data provided on the coding form, and all necessary software - written in MicroSoft Basic - for data handling and analysis. The use of this program permits a search for wastes which match any number of specific conditions (variable values), and is not restricted to a single condition. For example, it is possible to conduct a search for all wastes which contain a specific contaminant, and which are generated by a specific type of industry, and are located in a specific municipality.

## Results and Discussions

A total of 455 industries in the Region were contacted during the course of the inventory. The distribution of industries according to Regional areas (Kitchener, Waterloo, Cambridge, Townships) is summarized in Table 1. Of those contacted, 127 industries, equivalent to 27.9 percent of the total, do not generate any liquid or special wastes. Eight of the 455 industries contacted had ceased operating or were in the process of closing. A further five industries indicated during the interview that they do not generate any liquid or special wastes; however, based on the process descriptions and product lines, it was felt that some wastes would probably be produced from these operations. Only three industries, or less than one percent of those contacted, were unwilling to co-operate in providing information with respect to the generation and handling of liquid and special wastes.

TABLE 1. SUMMARY OF INDUSTRY CONTACTS BY REGIONAL AREA

| | KITCHENER | WATERLOO | CAMBRIDGE | TOWNSHIPS | TOTAL REGION | % OF TOTAL INDUSTRIES |
|---|---|---|---|---|---|---|
| Number of Industries Contacted | 165 | 94 | 142 | 54 | 455 | - |
| Number of Industries That Had No Wastes | 53 | 27 | 36 | 11 | 127 | 27.9 |
| Number of On-Site Interviews | 24 | 11 | 15 | 8 | 58 | 18.6* |
| Number of Process Flowsheets Generated | 12 | 10 | 18 | 8 | 48 | 15.4* |
| Number of Individual Wastes Generated | 227 | 113 | 218 | 95 | 653 | - |

* Expressed as percentage of industries that reported wastes (312 industries)

From the 312 industries which generated some form of liquid or special waste, a total of 653 individual wastes were identified, distributed as shown in Table 1. For more than 80 percent of these wastes (530 individual wastes), satisfactory information was obtained from the industry contact with respect to the types of contaminants present and the handling and disposal practices used. In the remaining cases (123 wastes or 18.8 percent of the total), certain critical information regarding the waste could not be obtained from the industry.

Few industries had quantitative information with respect to the characteristics of the individual wastes. pH data were recorded for only 89 wastes or approximately 12.7 percent of the total. Solids concentration data were available for 99 wastes (15.2 percent). In more than half of these cases, the pH and solids concentration data were estimated by the interviewer based on the information on waste composition provided by the industry. None of the industries contacted provided analytical data characterizing the concentration of contaminants in the wastes.

As shown in Table 1, on-site interviews were conducted with a total of 58 industries, equivalent to approximately 20 percent of those industries which produced some type of liquid or special waste. From these industries, process flowsheets were generated for 48 cases.

## Total Quantities of Wastes Generated

For purposes of this study, liquid and special wastes were quantified in either Imperial gallons (if they were clearly liquid wastes) or in tons (if they were judged to have a total solids content greater than approximately 25 percent). The total quantity of liquid and special wastes is reported in wet tons per year, determined by the direct conversion of the volume of liquid wastes to a wet weight equivalent in tons.

The total quantities of liquid and special wastes generated in the Regional Municipality of Waterloo are summarized in Table 2, classified by regional area. These data are presented graphically in Figure 2. The total volume of liquid wastes is approximately 9,952,000 Igal/yr and the total weight of the solid wastes is approximately 182,100 tons/yr. Thus, the total quantity of liquid and special wastes generated annually is approximately 231,900 wet tons. Industry in the Townships (Woolich, Wellesley, Wilmot and North Dumfries) is responsible for the generation of over 60 percent of the liquid wastes, while the City of Kitchener generates approximately 26.4 percent of the liquid wastes.

Industries in the cities of Cambridge and Kitchener generate approximately 52.9 percent and 36.2 percent of the solid wastes, respectively.

TABLE 2. SUMMARY OF WASTE QUANTITIES GENERATED BY REGIONAL AREA

| | KITCHENER | WATERLOO | CAMBRIDGE | TOWNSHIPS | TOTAL |
|---|---|---|---|---|---|
| Volume (Igal/yr) | 2,629,295 | 326,235 | 977,255 | 6,019,500 | 9,952,285 |
| % of Total Liquid Wastes in Region | 26.4 | 3.2 | 9.8 | 60.6 | 100.0 |
| Weight (Tons/yr) | 65,842 | 476 | 96,323 | 19,441 | 182,082 |
| % of Total Solid Wastes in Region | 36.2 | 0.3 | 52.9 | 10.6 | 100.0 |

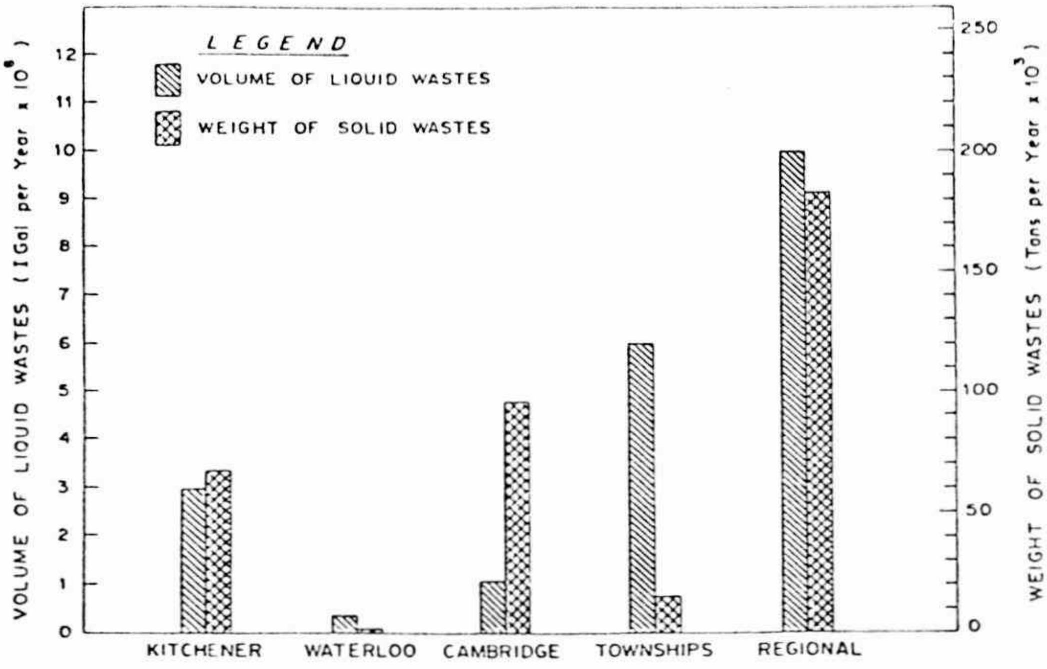


FIGURE 2 – DISTRIBUTION OF LIQUID AND SPECIAL INDUSTRIAL WASTES IN THE REGIONAL MUNICIPALITY OF WATERLOO

Table 3 describes the distribution of Regional wastes in terms of quantities of individual wastes generated annually. A major fraction (more than 60 percent) of the individual wastes for which quantitative data are available are generated at a rate of less than 1,000 Igal/yr or 5 tons/yr. However, these wastes represent less than 1 percent of the total quantity of waste generated in the Region. Wastes generated at annual rates exceeding 10,000 Igal/yr or 50 tons/yr account for only 20 percent of the number of wastes in the Region but represent more than 96 percent of the total quantity of Regional wastes.

TABLE 3. DISTRIBUTION OF WASTES BY QUANTITY IN THE REGION

| QUANTITY OF WASTE Tons/yr or Igal/yr | TOTAL NUMBER OF WASTES | LIQUID WASTES | | SOLID WASTES | |
|---|---|---|---|---|---|
| | | TOTAL QUANTITY (Igal/yr) | % OF TOTAL QUANTITY | TOTAL QUANTITY (tons/yr) | % OF TOTAL QUANTITY |
| <5 or <1,000 | 387 | 71,050 | 0.7 | 69 | <0.1 |
| 5 - 50 or 1,000 - 10,000 | 117 | 320,655 | 3.2 | 753 | 0.5 |
| >50 or >10,000 | 125 | 9,560,580 | 96.1 | 181,260 | 99.5 |

## Quantities of Individual Waste Types Generated

Wastes generated in each regional area and for the Regional Municipality were categorized according to waste type. A total of 41 individual waste types in six major categories (Organic Liquids, Inorganic Liquids, Organic Sludges, Inorganic Sludges, Solid Wastes and Miscellaneous Special Wastes) were identified during the course of the waste inventory.

Figure 3 summarizes graphically the quantities of liquid and solid wastes generated in the member municipalities and in the Region for each of the six major waste categories. The relatively small contribution of Waterloo industry to the total Regional waste production is evident. In Kitchener and Cambridge, Solid Wastes represent the principle waste category, accounting for almost 95 percent of the total Solid Wastes generated in the Region. Organic Sludges make up a large portion of the remainder of the Kitchener and Cambridge total waste. In the Townships, Organic and Inorganic Liquid Wastes, Organic Sludges and Solid Wastes all contribute significantly to the total waste quantity generated.

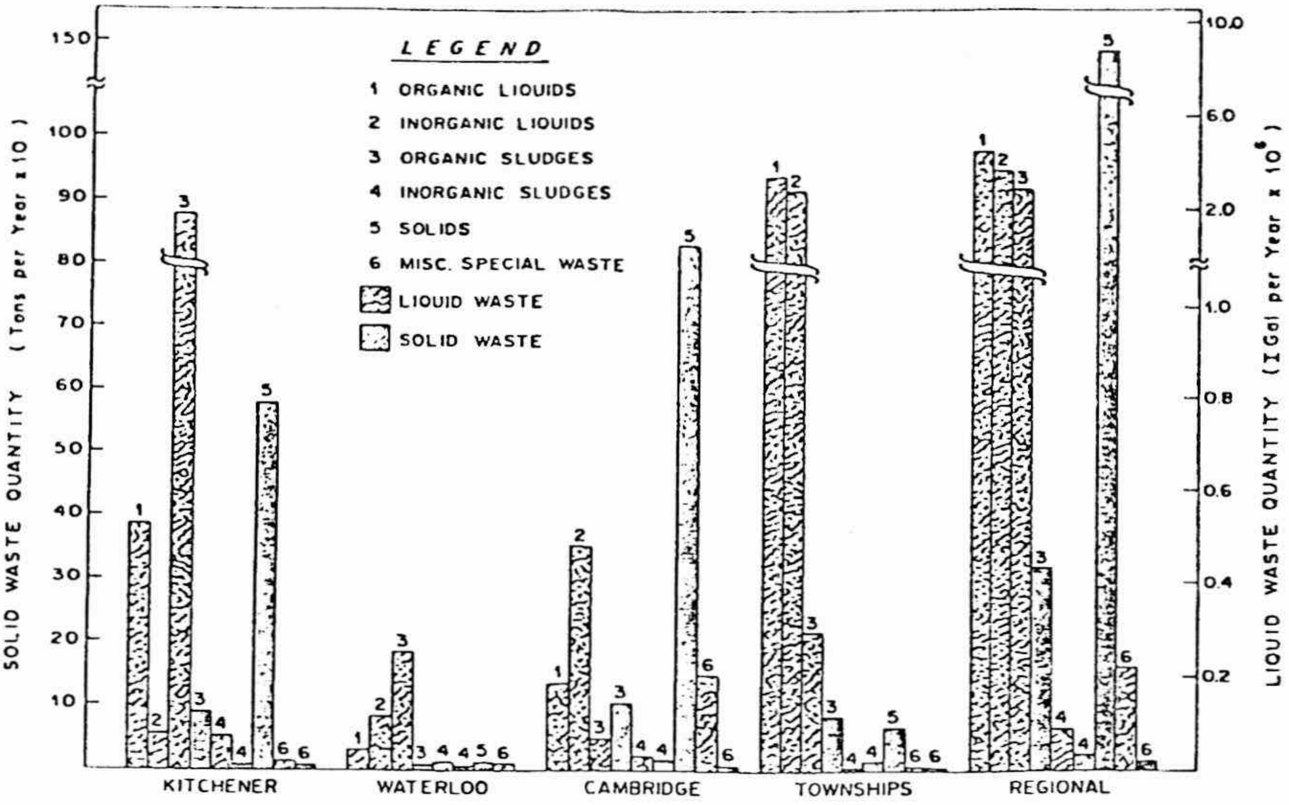


FIGURE 3 — QUANTITIES OF WASTE CATEGORIES GENERATED BY INDIVIDUAL REGIONAL AREAS

Regionally, the total quantity of Miscellaneous Special Wastes which includes such specific waste types as pesticides and herbicides, PCBs, pathological wastes, explosives, asbestos-containing wastes, radioactive wastes and miscellaneous laboratory wastes, amounts to 208,105 Igal and 193 tons/yr.

Food-related industries, primary metal and metal finishing industries and chemical and allied industries are the most significant contributors of liquid and special wastes. Food related industries alone account for approximately 5,772,000 Igal/yr and 72,038 tons/yr of liquid and solid wastes, respectively. Foundry sands account for approximately 50 percent of the special solid wastes generated in the Region.

With the exception of food-related wastes and foundry sand, only acidic and alkali solutions and miscellaneous inorganic liquids contribute more than 5 percent each to the total quantity of either liquid or solid wastes. The other fraction of the total is distributed over the remaining 37 waste type subcategories.

TABLE 4. SUMMARY OF STORAGE METHODS USED FOR LIQUID AND SPECIAL INDUSTRIAL WASTES

| STORAGE METHOD CODE | STORAGE METHOD | NUMBER OF WASTES | LIQUID WASTE | | SOLID WASTE | |
|---|---|---|---|---|---|---|
| | | | TOTAL QUANTITY IGAL/YR | % OF TOTAL QUANTITY | TOTAL QUANTITY TONS/YR | % OF TOTAL QUANTITY |
| 1 | Pits/Lagoons | 8 | 49,000 | 0.5 | 2,002 | 1.1 |
| 2 | Drums | 220 | 229,165 | 2.3 | 2,593 | 1.4 |
| 3 | Tanks | 100 | 6,965,320 | 70.0 | 35,995 | 19.8 |
| 4 | 5 Gal Pails/ Jugs | 56 | 12,134 | 0.1 | 0 | 0.0 |
| 5 | Wooden Boxes | 7 | 0 | 0.0 | 15 | 0.0 |
| 6 | Piles | 17 | 0 | 0.0 | 12,164 | 6.7 |
| 7 | Disposal Bins | 88 | 1,244,630 | 12.5 | 119.088 | 65.4 |
| 8 | Within Process | 118 | 1,435,515 | 14.4 | 8,621 | 4.7 |
| 9 | Not Stored | 32 | 12,318 | 0.1 | 598 | 0.3 |
| - | Unknown | 7 | 4,203 | 0.1 | 1,006 | 0.6 |
| Total | | 653 | 9,952,285 | 100.0 | 182,082 | 100.0 |

A significant quantity of waste materials accumulates in batch reactors, settling pits, sumps and recirculation systems within the industrial processes. These materials are removed on an intermittent basis for disposal and separate on-site storage facilities are not normally provided.

In terms of the number of wastes generated, there is no significant trend in the storage time provided prior to disposal. As shown in Table 5, 37.5 percent of the 653 wastes are stored less than one month compared to 31.0 percent of the wastes which are stored for nine months and longer on-site prior to final disposal. However, it is evident that wastes that are stored for longer than one month represent mainly wastes that are generated in small quantities. More than 94 percent of the total quantity of liquid wastes generated in the Region and more than 98 percent of the solid wastes are removed from the industrial site within one month or less.

## Relationship Between Industry Characteristics and Waste Generation

Large industries (employing more than 250 people) generate more than 42 percent of the total liquid wastes and 36 percent of the total solid wastes in the Region, although they represent less than 10 percent of the total number of industries contacted. Small industry (less than 100 employees) generated only approximately 46 percent of the total liquid and less than 14 percent of the solid waste quantity despite representing more than 70 percent of industries in the Region.

On an industry wide basis, there is no apparent correlation between number of employees and quantity of waste generated. However, it is possible that a more detailed analysis of the data from individual industrial classifications might yield a better correlation between waste generated and number of employees within each classification.

Similarly, there is no apparent correlation between water use and waste generation on an industrial basis. Industries reporting daily water consumption in excess of 1,000,000 IGPD are responsible for approximately one-third of the total liquid waste quantified. However, industries reporting water usage of less than 10,000 IGPD are responsible for an almost equal quantity of liquid waste (23 percent of the total).

## Waste Handling Practices

More than one-third (33.7 percent) of the 653 individual wastes generated in the Region are stored in drums, according to the summary of storage methods presented in Table 4. However, this storage method is generally utilized for wastes generated in small quantities as less than 2.5 percent of the total Regional liquid waste quantity and less than 1.5 percent of the solid waste is handled by this method. Wastes generated in large quantities are typically stored in tanks prior to disposal. Approximately 15 percent of the 653 wastes are handled in this manner, but this represents 70 percent of the total quantity of liquid wastes and 20 percent of the total quantity of solid wastes.

Disposal bins and piles are typically used for storing solid wastes, such as foundry sands, and food processing solid residues. A significant number of the liquid wastes stored in disposal bins are oils and solvents which are co-disposed with other solids wastes by this method. Approximately 1,100,000 Igal/yr of the liquid quantity being stored in disposal bins is wet food processing sludge.

TABLE 5. SUMMARY OF STORAGE TIME FOR LIQUID AND SPECIAL INDUSTRIAL WASTES

| STORAGE TIME | NUMBER OF WASTES | % OF TOTAL NUMBER OF WASTES | LIQUID WASTE | | SOLID WASTE | |
|---|---|---|---|---|---|---|
| | | | TOTAL QUANTITY IGAL/YR | % OF TOTAL QUANTITY | TOTAL QUANTITY TONS/YR | % OF TOTAL QUANTITY |
| One Month and Less | 245 | 37.5 | 9,411,360 | 94.6 | 178,726 | 98.2 |
| Between Two and Eight Months | 194 | 29.7 | 471,716 | 4.7 | 860 | 0.5 |
| Nine Months and Greater | 197 | 31.0 | 64,593 | 0.6 | 2,300 | 1.2 |
| Unknown | 17 | 2.6 | 4,616 | 0.1 | 96 | 0.1 |
| TOTAL | 653 | 100.0 | 9,952,285 | 100.0 | 182,082 | 100.0 |

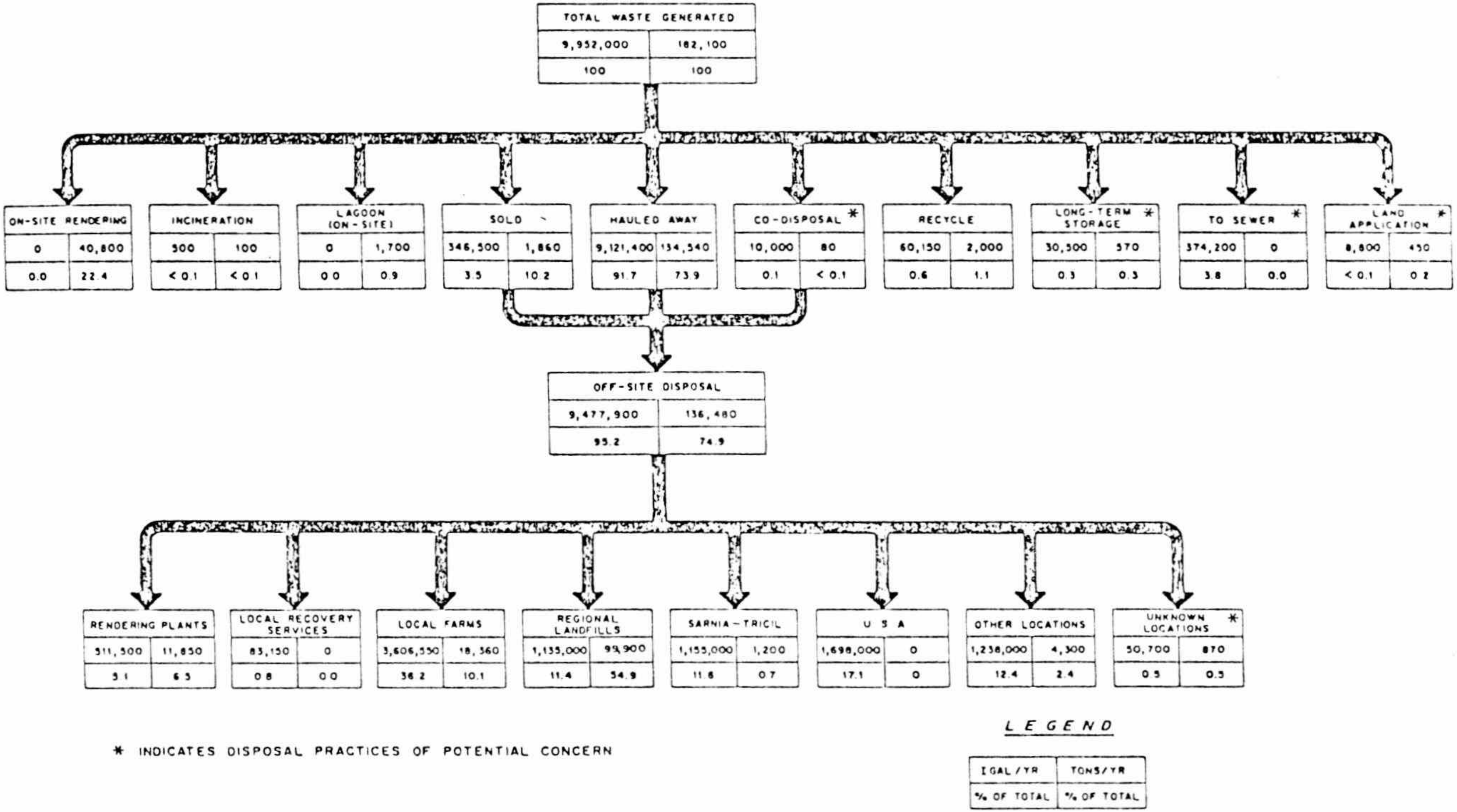
## Fate of Liquid and Special Wastes in the Region of Waterloo

Figure 4 summarizes the fate of liquid and special wastes generated in the Regional Municipality of Waterloo in terms of the disposal methods and disposal locations.

The vast majority of wastes generated by Regional industry are hauled away from the source. If a potential for resource recovery exists for the industry generating the waste, it appears that such recycling schemes are presently being practiced in most cases.

Approximately 30 percent of the liquid wastes and less than 1 percent of the solid wastes generated in the Region, exclusive of food industry wastes, are presently being removed from the Region, for disposal and/or recovery. Facilities within the Region handle approximately 7,083,000 Igal and 180,900 tons of waste materials annually. Local recovery services are available to handle used lubricating oils, cutting fluids and most solvents and are presently treating almost all of these waste materials.

Wastes which are not presently handled within the Region are primarily Inorganic and Organic Liquids and Organic Sludges. Disposal of these materials is approximately equally divided between the Tricil facility at Sarnia and the United States. Total quantity of liquid and special wastes removed from the Region of Waterloo annually is approximately 2,954,000 Igal and 1,200 tons, exclusive of food-related wastes handled by renderers outside the Region.



* INDICATES DISPOSAL PRACTICES OF POTENTIAL CONCERN

FIGURE 4 - FATE OF LIQUID AND SPECIAL WASTES IN THE REGION OF WATERLOO

Although the vast majority of waste materials which are generated within the Region are presently being handled by environmentally-acceptable methods, a number of examples of questionable disposal practices were identified. Approximately 8,800 Igal/yr and 450 tons/yr of a wide variety of liquid and solid wastes are disposed of on the property at the industrial source. In most cases, this represents small quantities (<100 Igal/year) of used lubricating oils and cutting fluids; however, in some cases, organic solvents and a variety of sludges are also disposed of by this method.

Long-term storage of approximately 30,500 Igal/yr and 570 tons/yr of liquid and special wastes represents a potential problem and, in most cases, is unnecessary as suitable disposal locations or methods are available for the majority of these wastes. The exception is eight wastes containing PCBs, for which no acceptable disposal method is currently available.

Approximately 374,200 Igal/yr of liquid industrial wastes which are included in the inventory are received by Regional sewers. Landfill sites in the Region receive approximately 4,000 Igal/yr of Organic Liquids, the majority being mixed with sanitary garbage in small quantities and co-disposed. The former disposal method may be acceptable depending on the waste constituents and quantities. The latter disposal method is environmentally unacceptable and alternate methods are available for disposal of these materials.

The fate of only a small fraction (less than 1 percent) of the total wastes generated in the Region could not be firmly established based on the inventory data. This fraction includes 50,000 Igal/yr and 31 tons/yr of Organic and Inorganic Liquids and Sludges.

## Conclusions

Based on the results of the inventory, the following major conclusions are drawn:

- A total of 9,952,000 Igal/year of liquid wastes and 182,100 tons/year of special solid wastes are presently generated in the Regional Municipality of Waterloo. This is equivalent to a total annual waste generation of 231,900 wet tons.
- Food-related industries generate 5,772,000 Igal/year of liquid wastes and 72,038 tons/year of solid wastes. Foundry sand from primary metal

wastes. Other major waste types identified during the inventory are acidic and alkali solutions and miscellaneous inorganic liquids.

- Few industries had quantitative data on waste characteristics.
- The majority of the wastes generated in the Region are presently being handled within the Region. Wastes being removed from the Region for disposal are primarily inorganic and organic liquids and organic sludges which are presently being handled by Tricil at Sarnia and in the United States.
- Specific areas of concern identified during the inventory include:
  i) land application on-site of oils, cutting fluids and solvents,
  ii) the unnecessary long-term storage of a variety of wastes,
  iii) the co-disposal of small quantities of liquid wastes to landfills,
  iv) the disposal of liquid wastes to the Regional sewer system,
  v) the unknown fate of approximately 50,000 Igal/year of liquid wastes and 31 tons/year of special solid wastes.

## Acknowledgements

The consultants would like to acknowledge the co-operation shown by Regional industry during the course of the inventory interviews and the direction provided by the Study Steering Committee which comprised representatives of the Chambers of Commerce, the Regional Municipality of Waterloo, the Ontario Ministry of the Environment and Environment Canada.

# TRICIL'S NEW INCINERATION PLANT AND THE COMPANY'S EXPERIENCE WITH THE HEARING FOR THE PROJECT

by

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## Introduction

Tricil has recently begun construction in Sarnia on a new incineration system, to replace the existing plant. This follows three years of research and development, process design, and environmental approvals. There are many unique features to this project which make it a major step forward in industrial waste treatment in North America. This paper addresses two major aspects of the project; plant design and environmental approvals.

## 1. Plant Design

Before describing the process components in detail, it would be worthwhile to describe the basic concept and how it was developed.

The existing incinerator destroys organic liquids at high temperatures and the products of combustion are discharged directly to the atmosphere together with a great deal of waste heat. Emissions are maintained within the regulations by exercising strict control over the incoming waste products and incinerator feed stock. This also tends to restrict the flexibility of the incinerator.

In the new system the hot combustion gases will be partially cooled with an air-cooled heat exchanger, passed through a spray dryer and baghouse, and discharged to the atmosphere. In the spray dryer, pretreated alkaline waste material will be injected into the hot gas stream. The alkaline liquid will be evaporated to dryness, the majority of the acid gases generated in the incinerator will be neutralized, and the flue gas temperature reduced to 200°C. The alkali is converted to a dry, free-flowing powder. The baghouse removes the majority of suspended particulate from the gas stream.

The basic concept was first developed in the spring of 1979. Preliminary calculations indicated that the concept was feasible, and a series of experiments, conducted at the test facilities of a spray dryer manufacturer, confirmed this. During 1980 a small spray dryer was purchased and a pilot plant system, designed and built by Tricil, was installed in Sarnia. Actual stack gases were used as the feed stream to the pilot plant. The pilot plant consisted of a pre- quench chamber, spray dryer, cyclone, baghouse and fan. The fan discharge was returned to the incinerator so the system could operate in closed circuit. Testing began in late 1980 and was completed in the spring of 1981. The purpose of the pilot program was to measure the effects of temperature drop, final temperature, solids content in the spray dryer feed, moisture content of the gas stream, cyclone and baghouse collection efficiencies, and to collect samples of spray dryed solids for further testing. Ontario Research Foundation were contracted to assist Tricil in the test program.

Samples of collected solids were used to conduct pelletizing tests in the pilot facilities of an equipment manufacturer.

The results of the test program provided all the necessary data to specify the design basis for the full scale system including temperature drop, final temperature, alkaline solids content, gas moisture content, gas residence time, and air-to-cloth ratio. In addition, the tests indicated that the use of cyclones would be neither helpful nor desireable and these were therefore eliminated from the design.

Final design was completed by the spring of 1981 and this formed the basis for Tricil's application to the Ministry of the Environment.

## 2. Process Components

The following sections describe some of the principle design features of the major process components of the new plant.

### a) Incinerator

The incinerator is a horizontal unit with circular cross-section, 3.7 metres in diameter and 13.7 metres long. In the primary zone rich organic wastes are burned at a temperature between 1300 and 1400°C at 85% excess air with a gas residence time of 0.9 seconds. Lean wastes are injected into the products of combustion. In the secondary zone, following lean injection, the temperature is between 750 and 825°C at 55% excess air with a residence time of 1.5 seconds. These conditions are more rigorous in all respects than the conditions in the existing Sarnia incinerator, which has been found in numerous test programs to comply with all the regulations of the Ministry of the Environment.

### b) Heat Exchanger

The gases from the incinerator are prequenched to 700°C, and pass into a vertical air-cooled heat exchanger. The exit temperature from the heat exchanger is 450°C. Provision has been made to use the waste heat as preheated combustion air at a later date.

c) Spray Dryer

The gases enter the spray dryer chamber at 450°C, are quenched with alkali and water supplied through separate nozzle systems, and exit at 200°C. A portion of the dry solids (about 20%) is collected at the bottom of the spray dryer and discharged through a rotary valve. The balance of particulate leaves the spray dryer with the gas stream.

d) Baghouse

The baghouse is a four compartment unit with a total of 1,080 bags, giving an air-to-cloth ratio of 3.2:1 at mean flow and 4.9:1 at maximum flow. The system is equipped with a bypass for start-up and shutdown, and has the capability for both on-line and off-line cleaning. The overall efficiency of the gas cleaning system is as follows:

HCl - greater than 85%
$SO_2$ - greater than 75%
Particulate - greater than 99%

e) Ash Handling System

Ash residues are collected at three points, the incinerator, the spray dryer and the baghouse. The material is transferred by enclosed screw conveyors to a bucket elevator and to a storage silo. The solid material, which can be characterized as a light free-flowing powder, is then processed through a pelletizer, to eliminate dust problems and discharged to a container for transportation to the landfill.

f) Stack

The replacement stack will be 225 feet in height and insulated.

g) Alkaline Tankage

Alkaline liquids and sludges will be received into an inground receiving tank, transferred to two storage tanks, and processed over vibrating screens to remove coarse suspended solids. Finally, the alkaline material will be blended with process water to give the appropriate feed stock for the spray dryer.

h) Organic Tankage

A second organic separation tank is being added to extend the available time for phase separation.

i) Instrumentation

The system is equipped with appropriate instrumentation throughout to ensure that the important process parameters are continuously monitored. Warning devices throughout the system identify conditions outside normal operating ranges.

All of the feed lines to the incinerator and spray dryer are equipped with automatic composite samplers. The twenty-four hour composite samples obtained are analysed on a daily basis to provide an accurate record of the feed to the system. Temperatures throughout the system are continuously monitored and recorded. The monitoring of final emissions is described in a subsequent section.

### j) Operations Building

As part of the project, a new building is being constructed to house the incinerator and other process equipment, and to provide a number of important support facilities. These include a new lab of about 1,000 $ft^2$ in area, a maintenance shop with a high bay area, new facilities for the operators including showers, change rooms and a lunchroom, some additional office space, the boiler room and the motor control centre.

Because of the extent of the modifications, it has also been necessary to upgrade the electrical supply to the plant, install a gas line and convert the entire plant to natural gas, and install a main water supply line. The water supply is the most difficult of these because the distance from the nearest existing main is greater than 4 miles. The line has been sized to provide sufficient surplus capacity for Tricil's neighbours should they wish to tie into the new supply line.

## 3. Environmental Protection and Design Safeguards

The basic design of the plant is such that environmental protection is maximized. The incinerator design, combined with the spray dryer and baghouse insure that all emissions are just a small fraction of the levels permitted by Ontario regulations. Also, by lowering the stack gas temperature, it has been possible to install a more comprehensive stack monitoring system including opacity monitor, hydrocarbon analyser, and $SO_2$ analyser.

The reduction of alkaline sludge materials to dry solid pellets will result in a reduction in landfill utilization for process residues, and is an additional benefit.

Many of the details of the design have been incorporated to ensure operational integrity and employee safety. Apart from the stack monitoring system, the entire process is heavily instrumented with all the information being transmitted to the central control room. The automatic ash removal system minimizes operator contact with this material. The automatic temperature control system in the spray dryer maintains the gas temperature within tight operating limits to protect the baghouse and other downstream components. A relief stack, which opens under conditions of incinerator overpressure, has been incorporated. The plant shutdown sequences have been, to a large extent, automated to minimize the possibility of human error. The baghouse has been overdesigned, so that one compartment can be taken off-line for bag maintenance without necessarily shutting the plant down. A baghouse bypass has been provided for start-up and shutdown to prevent condensation on the bags. An emergency water quench system has been provided in the spray dryer in the event that the alkaline waste material feed should fail. All the controls for the plant are located in a remote, air conditioned, control room. Finally, a hydraulic hoist is being installed at the unloading station to enable the operator to sample trucks from the top, without having to climb up and down ladders with sample jars and sampling equipment in his hands.

## 4. Capabilities of the New System

The construction of this new modern facility will provide Ontario's waste generating industries with a sophisticated, environmentally safe outlet for most of their by-products through the 1980's and 90's. Besides being a replacement for the existing incinerator, the new system does of course have a broader range of capabilities. For example, the inclusion of air emission control equipment will impose less restrictive ash content constraints on the incoming waste materials. This is particularly important in that it will permit Tricil to incinerate inorganic materials that are contaminated with organics unsuitable for other types of treatment. The new Certificate of Approval also permits Tricil to receive and incinerate organic materials contaminated with low levels of chlorinated solvents. There is a significant number of wastes which falls into this category. The increased capacity for storage is an obvious benefit, and the improvement in the organic/aqueous separation which this will provide will maximize the use of high energy content waste materials. The entire plant has been designed with a view to maximizing the throughput. It is significant that the maximum design throughput of the new incinerator will be unchanged from that of the existing system, but the actual throughput will be increased by approximately 20%.

The new system does have certain limitations, and it is important that these be understood. It is not approved for the incineration of chlorinated solvents or polychlorinated biphenyls. Also pesticide wastes can only be received and treated after prior consultation with, and approval by, the Ministry of the Environment.

Two broad classifications of inorganic liquids are beyond the present capabilities of this system, these are strong acids and cyanide containing wastes. But with these few exceptions the new system, in combination with Tricil's secure landfill, will provide a complete range of waste disposal services to industry.

## Environmental Approvals

Section 33(A) of the Environmental Protection Act states:

> "Where the Director receives an application for a Certificate of Approval for the use, operation, establishment, alteration, enlargement or extension of a waste disposal site for the disposal of hauled liquid industrial waste or hazardous waste --- the Director shall, before issuing or refusing to issue the Certificate of Approval, hold a public hearing."

In April of 1981, Tricil Limited submitted to the Ministry of the Environment an application for a Certificate of Approval for modifications to its liquid waste incinerator and transfer station in Moore Township.

The Ministry reviewed the application and advised that the alterations were of such magnitude that an Environmental Assessment Board Hearing would be necessary.

Environmental Assessment Board Hearing procedures are prescribed in legislation in order to:

i) advise the public of the proposals;

ii) permit public comment and reaction;

iii) allow the Assessment Board to weigh the views of all participants;

iv) ensure that the Board's recommendation is in the best interests of environmental protection within the terms of the Act.

Anyone who has participated in Public Hearings conducted by the Environmental Assessment Board, is aware that the procedure is similar to that used in the court system. Representations are made to the Hearing Panel by the participants, or their counsel, and each party has the right to cross-examination and redirect examination.

Evidence is formally recorded by a court reporter, and on completion of the Hearing, the panel prepares its findings and recommendations, and submits them to the Director. This usually takes several weeks.

The hearing process is therefore, by design, an adversarial institution, although the Chairman has considerable discretionary powers which he or she will use to ensure adequate communication between the parties and the Board.

The Tricil modifications are significant in that the completed plant will represent a major technological advance in the treatment of liquid industrial wastes in North America, resulting in increased versatility and efficiency and decreased residuals for disposal. As described earlier, the control mechanisms and methods of operation provide an even higher degree of environmental protection.

It was felt to be important that Tricil's neighbours in Moore Township, and interested people within the larger community, should be aware of the scope and extent of the modification proposals. To accomplish this, a series of public information sessions was held at the Sarnia plant where members of the public could talk with Tricil's operations and engineering staff, and learn how the modifications would affect Tricil's operation. Those interested have always been welcome to visit the Tricil plant and learn about its operation, and this invitation was again extended.

The public information sessions were designed to discuss details of the proposal with members of the public, not in any way to pre-empt the Public Hearing, nor to "drum-up" support for Tricil's proposal. Since the formal application to the Ministry is essentially a technical document, the time spent at these informal sessions, explaining the technical details to interested members of the public, was intended to make their participation in the Hearing itself more valuable.

Three information sessions were held - two evening and one daytime - and were advertised in local newspapers. In addition, immediate neighbours were personally invited by letter, as were members of the local Municipal Council from Moore Township.

By holding the information sessions several weeks prior to the Environmental Assessment Board Hearing, opponents of the proposals, if any, had sufficient time to prepare their case. It is important that the objectors to any proposal should be objecting to the proposal, not to what they think the proposal might be.

The information sessions were simple and informal. With the aid of wall charts and hand-out information, Tricil staff described the proposed changes and outlined the general methods of operation of the plant. Questions from the public were encouraged at all times and considerable time was devoted to general discussion.

Although attendance at all the sessions was small, questions and comments were quite representative of public opinion and public concerns.

A real interest, and an understanding of the proposed modifications were evident. However, much of the discussion centred on general waste management issues and on other parts of Tricil's operation, e.g. landfill, air and water monitoring and materials control. In this area too, explanation and discussion of these technical issues with those in attendance were felt to be valuable. It is not suggested that this type of discussion will allay all the concerns or fears of the public because there are no 100% answers to many of the questions and issues, no absolute certainty, only the application of the best available knowledge and technology.

Local media were well represented at the information sessions and details of the Tricil proposal and the responses were thus made known to a wider public.

The public hearing which took place in October 1981 attracted a much higher public attendance than did the information sessions, although almost all who had been at the information sessions also attended the hearing.

Concerns expressed to the Hearing panel by the members of the public addressed the broader waste management issues, the operation and control of the overall Tricil operation and the expectations of the Ministry of the Environment. The Hearing opened with the presentation of the proposal through questioning of Tricil's witnesses by Tricil counsel. Members of the Hearing Panel also addressed questions to the witnesses at this stage, counsel for the opponents were permitted to cross-examine, and the Chairman then permitted further cross-examination or questioning by members of the public and other interested parties.

The opponents then presented their witnesses in a similar fashion and cross-examination and questioning was again permitted.

The Hearing Panel then received statements or presentations from other interested parties, for example, the Lambton Anti-Pollution Association who presented a petition and formal submissions, dealing mainly with wider environmental issues than the modifications which were the subject of the Hearing. The view was expressed by several speakers that Tricil's proposed modifications were desirable and in fact to the overall benefit of industry, the environment and the local community.

Counsel for both the proponent and the opponents presented their closing arguments to the Panel and the Hearing concluded with a visit to the Tricil plant by the Hearing Panel and those members of the public who wished to attend.

The Environmental Assessment Board issued its report about 7 weeks after completion of the Hearing and recommended that approval be granted for the proposed alterations subject to 3 specific conditions. The conditions concerned materials to be processed; control of emission and monitoring of area ground water; and although the Board felt this latter issue to be peripheral to the subject matter of the Hearing, they believed sufficient concern had been expressed at the Hearing for the issue to be addressed in this way.

## Review of Hearing Process

In light of Tricil's experience with the approvals process, in this and other applicatons, a brief review from the proponents's perspective may be useful. A discussion of the functions of the various participants, the proponents, the opponents, the Hearing Panel, the Ministry of the Environment and the public, will illustrate this perspective.

The proponent has most control over the outcome of the Hearing. He must ensure that his presentation is sufficiently complete that it can answer questions and concerns from the Hearing Panel, from the opponents and from the general public. It is also important that the information be available early enough, and that it be complete enough, to minimize the possibility of an adjournment.

The opponents have the right, even the responsibility, to request an adjournment if information is incomplete or not fully understood, and the Hearing Panel will grant this when the reasons are valid. The Chairman can order an adjournment whenever he feels that issues are incompletely or incorrectly presented.

Long and frequent adjournments to the Hearing Process are difficult and expensive for both proponents and opponents alike and many months may pass before the Hearing can be reconvened.

The proponent must have available, at the time of the Hearing, those expert witnesses who will be required to explain, expand or defend the technical details of the proposal and the witness must be able to explain these aspects not only to the panel and the opponent's experts, but also to non-technical members of the public who have a right to know and understand technical details of the proposal.

In summary, it is the proponents responsibility to provide a technically complete proposal at such a time and in such a way that it is understandable by the members of the general public.

The opponents also have a major responsibility for the success of the Hearing process, not unlike that of the proponent. The "success of the Hearing process" depends upon a fair and balanced review of all evidence and points of view; it does not necessarily mean the approval of the proposal.

While the primary function of opponents is to oppose, they also must recognize that their opposition will be evaluated within the terms of reference of the legislation and within the jurisdication of the Hearing Panel.

Just as the proponent has the responsibility to ensure timely provision of adequate detail, so have the opponents the responsibility to address the information provided in preparation of their presentation. That is not to say that they must base their opposition only on the detail contained in the proposal, but that where information in the proposal addresses their concerns they must consider that information.

In the case of the recent Tricil hearings, opponents to the proposal presented to the Board their concerns in a clear and lucid fashion. These concerns were not based exclusively on the content of the proposal, nor on the subject matter of the hearing, but on more general concerns about the effects of waste management operations and the future of waste management in the Province.

In those areas where the concerns had been addressed in the Tricil proposal the information was taken into account.

Once again the opponents must have prepared their case in similar detail to the proposal, using the available information in the proposal and equipping themselves with adequate expert witnesses in those ares where technical details may be in dispute. Where the opposition to a proposal is based on a broader perspective than the information contained in the proposal, the opponents have the responsibility to prepare their case in adequate depth. In this case, there is no requirement for prior disclosure to the proponent, who must therefore have adequate answers to all possible criticisms! This may be a major reason for adjournment or delays in the Public Hearing process and the only way for the proponent to prevent this happening is by detailed preparation before the Hearing.

The Hearing Panel, appointed by the Environmental Assessment Board, controls the Hearing, but as pointed out before, the Chairman has a degree of discretionary power to permit a relaxation of formality. In the case of the Tricil hearing this allowed very free and broad ranging discussion among all parties involved. It is not the function of the Hearing Panel to evaluate the technical detail of the proposal, this is the responsibility of the MOE Approvals Branch. However, in addressing a technical proposal, members of the panel are assisted by their environmental and engineering advisor.

The role of the Ministry of the Environment in the Hearing process is one which is often misconstrued. In fact, the regional or approvals section of the MOE have no function at the Hearing unless at the request of the Hearing Panel, the proponent or the opponents. Ministry staff can be called to testify or to advise the Hearing Panel as required, but it would be possible for a hearing to proceed without any direct MOE involvement.

The major function of the Ministry within the Public Hearing process should be that of technical referee. They must decide whether a proposal is technically sound and sufficiently detailed to go forward for a Public Hearing and it is the MOE who have the ultimate responsibility for issuing or refusing to issue the Certificate of Approval, after the Environmental Assessment Board makes its recommendations.

The Ministry should avoid aligning itself with either the proponent or the opponents, must judge the case on its technical merits and on the Hearing Panel's evaluation and recommendation, and must be seen to be neutral.

In the Tricil hearing, a representative from the Sarnia district office of the MOE was called by Moore Township to give evidence concerning ground water monitoring and quality in the area. Although this was ruled by the Panel to be peripheral to the subject matter of the Hearing, the evidence was admissable and, as mentioned earlier, was referenced in one of the conditions recommended by the Board.

Since the subject under discussion is called a Public Hearing, it is appropriate that the role of the public be left to the end; they must live with the results of the actions of the previous four participants, and it is for them that the procedure was first devised.

The existence of opponents to the proposal has been assumed, and while these opponents are viewed as being part of the public, it should be remembered that they are very often a small part of the public, and representative of very specific interests.

The public at large are those to whom the government, through the Hearing Panel, is responsible. The "not in my back yard" syndrome has surfaced and been discussed at many previous conferences such as this. It is vital that everyone be very much aware that waste management facilities, along with other industrial enterprises, must go in someone's back yard in order that this generation's desired lifestyle can proceed without widespread damage to the environment.

The Public Hearing process is not one which is designed to protect one set of vested interests against another, rather to ensure that the best interests of the public are protected. In order for the system to work, each participant must really accept his responsibility and must approach the Hearing in a positive and productive way.

# EFFECTIVE AND SAFE DISPOSAL OF INDUSTRIAL WASTE STABLEX (CANADA) LIMITED

by

Pierre Grenier
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Stablex (Canada) Limited
Blainville, Que.

## INTRODUCTION

I thank the organizers of this 29th Ontario Industrial Waste Conference for the opportunity to address the conference.

We believe that our company Stablex (Canada) Limited can make a substantial contribution to the management of industrial wastes and help protect the environment.

Both government and private sectors recognize that effective long-term disposal of hazardous industrial waste is emerging as the critical environmental issue of the 1980's. This paper will review technology utilized in England and soon in Canada for safely treating and disposing of a broad range of toxic and hazardous wastes generated by industry.

Although this technology is the backbone of our enterprise, it can be applied only if we gain public acceptance. In addition success will depend on how much industry utilizes our service. For these reasons, I will discuss our successful public relations campaign in Quebec and touch upon some relevant marketing issues.

## BACKGROUND

Stablex (Canada) Limited and their shareholders, Rio Tinto Zinc Corporation Limited (92%) and Leigh Interests (8%), have identified this need in highly industrialized societies for well managed, scientifically operated, industrial waste treatment centers. The satisfaction of that need was seen as a long term business opportunity and therefore the firm has applied the necessary human and financial resources to fulfill it.

In the early 1970's researchers and engineers working at an environmental control laboratory in England developed what is now the patented Sealosafe $^{SM}$ process, to convert many of the industrial by-product wastes to a useful material that exhibits exceptionally good environmental compatibility and structural integrity.

In the Midlands (England), a shareholder company, Leigh Interest Limited has been operating waste management facilities for many years and began commercial operation with the Sealosafe technology to treat inorganic industrial wastes in 1974.

The West Thurrock facility, near London U.K., came on stream in January 1978. The capacity of this facility is 400,000 tons per year. Operating experience with this facility has since proven the Sealosafe technology. Over the years, the company has collected data on the treatment of industrial wastes from over 2,000 sources. This information would be available to the management on any new Stablex facility. Stablex (Canada) Limited will rely on this experience in developing management schemes for regional treatment facilities in Canada.

In the U.S.A., Stablex Corporation has been active since 1976 promoting projects throughout the country. The State of Michigan has issued the necessary permits for the construction of a plant in Groveland Township, some 40 miles north of Detroit. Construction has been delayed pending resolution of a local zoning dispute.

The Environmental Protection Agency in the United States saw fit in November 1980 to grant an interim delisting to the STABLEX final product resulting from the treatment of twenty-nine specific categories of hazardous inorganic wastes to be treated in Michigan.

Stablex Reutter Incorporated operates a laboratory facility in Camden, New Jersey, that specializes in the analysis and treatment of wastewater and hazardous and toxic industrial wastes. Another function of Stablex Reutter is to provide technical service to the operating Stablex divisions and fulfill some of their research and development needs.

During 1980, the Quebec Government chose Stablex (Canada) Limited to undertake Phase I of an integrated industrial waste treatment center in that province. Jointly with the Ministry of Environment, Stablex (Canada) Limited proceeded with site identification, environmental and social impact studies, public hearings and permit application procedures. In May 1981, the Executive Committee of the Quebec Government passed an Order in Council requiring that a certificate be issued enabling Stablex (Canada) Limited to proceed with the construction of a 20 million dollars facility. The permits were issued in early 1982 and construction started on March 2nd, 1982. Operation will begin during the first quarter of 1983.

## THE PROCESS

Most compounds and elements, essentially heavy metals, usually identified as hazardous inorganic waste were initially water insoluble, environmentally inert natural ores. It is in the process of extracting and transforming those ores that man has made them water soluble, and thereby accessible and reactive with living organism. Stablex through further chemical and physical changes is returning those compounds and elements into a synthetic, water insoluble solid material that behaves like natural ore.

In order to accomplish these transformations, the stablex process uses raw materials such as fly ash and cement. They give the product a durability and structural integrity similar to natural stone.

## Pre-treatment

The combination of chemical and physical reactions taking place in a Stablex Plant are complex and numerous. Depending upon the type of waste, an appropriate chemical pretreatment may be necessary. For example, cyanides are oxidized into cyanates with selected reagents and hexavalent chromium is reduced to trivalent. The objective of this pre-treatment is to convert the elements or compounds into a more stable, less reactive form prior to submitting them to the treatment and then the fixation/solidification, steps together with other suitable wastes.

## Treatment

This treatment is essentially a neutralization step followed by a total solid adjustment. Ideally the neutralizing agents are selected to yield insoluble salts and the total solids content is adjusted to take maximum advantages of the solidification characteristics of the hydrating agents used for solidification of the waste slurry.

## Fixation/Solidification

For this final step of the process, Stablex uses mainly Portland cement in combination with other puzzolonic materials such as fly ash or other type of alumina silicate dust. These treatment and fixation/solidification additives will fulfill many functions.

a) neutralization

One of the componant of cement, the clinker, is a salt of strong base CaO and weak acids (silica, alumina, iron oxide). In presence of strong acids, it will act as a strong base, liberate the weak acids, highly insoluble and usually capable of chemical and physical absorption.

The natural alkalinity of cement also provides a buffering effect capable of protecting the elements that have been solidified from acid rain attack. In fact the acid conditions will result in a strengthening of the fixation structure of the material.

### b) precipitation

The lime, the cement and puzzolonic additives will essentially supply calcium cation. Calcium salts can vary from being lightly to minutely soluble.Their presence will increase precipitation of many of the anions present in the industrial wastes such as, to name a few, phosphates, sulphates, arsenates, borates, fluorides, zircates, chromates, leadates, tungstates...

### c) absorption

One gramme of anhydrous cement having typically a specific surface area of 1 $m^2$/gr will generate an hydrated paste having a specific area 100 times bigger. In this hydratation process the cement and to some extent also the other reagent specifically selected by Stablex will develop physical and chemical absorption phenomena particularly interesting in the treatment of wastes.

### d) complexation

The hydrated cement is characterized by a high Ph (12 to 13). Under these conditions the aluminate ion forms numerous complex of which the trisulfoaluminate is the most reputed one. Many anions, other than sulfates will also form aluminate complex. For example Cl, Br, I, $NO_3$, $NO_2$, $M_nO_4$, $C_rO_4$ will form aluminate complex where calcium salts are pratically insoluble. This complexing function adds to the precipitation effect mentioned earlier and reduces solubilisation of many toxic ions.

For the past seven years, wastes from more than 2,000 different industrial sources have been successfully treated. Some of these are shown in Table I. The process is particularly successful in the disposal of arsenical, mercury, cyanide, and other noxious wastes.

## THE PRODUCT

The toxicity of an element is function of the damage it can cause to living organism when absorb in quantities exceeding a critical level. Within those limits some of them are useful and even essential to good functioning of life.

A compound or element is qualify hazardous only when it exists in a form that makes it readily available in harmful quantities. When properly treated and disposed of it no longer represents a hazard.

## TABLE I

## TYPICAL WASTES SUITABLE FOR FIXATION/SOLIDIFICATION

Mine Tailings
Dyestuff Liquors
Spent Catalysts
Sulphide Wastes
Pickling Acids
Incinerator Ashes
Tin Solutions
Mercury Salts
Filter Cakes
Copper Sludges
Cobalt Salts
Thicoyanates
Effluent Treatment Sludges

Tannin Residues
Acid Tars
Zinc Sludges
Spent Acids
Chrome Solutions
Fluorides
Cadmium Liquors
Sewage Sludges
Latex
Alkaline Solutions
Cyanide Solutions
Ion Exchange Resins
Electroplating Residues

Vanadium Powders
Asbestos Wastes
Solid Cyanides
Paint Wastes
Barium Sludges
Scrubbing Liquors
Arsenic Solids
Nickel Salts
Antimony Residues
Aluminum Sludges
Phosphates
Lead Solutions
Foundry Sand

The most important criteria in determining effective disposal in the assurance that toxicants trapped in the fixation/ solidification product do not re-enter the environment in volume that will cause harm. Before issuing permits required to build and operate plants, government agencies and independent testing laboratories have subjected the final product to exhaustive tests to satisfy the need for environmental safety.

Impermeability reduces the chance for leaching of any toxicant from the matrix. Utilizing a test method developed by E. Jadgwick ("Absorbtion and transmition of water by porous bodies") the British Ceramic Research Association confirmed the fact that the fixation/solidification polymer product demonstrated typical permeability of 1 X $10^{-7}$ cm/sec.

In order to interpret these findings it is useful to compare the results with other permeability data. Table 1 shows these comparisons and it can be seen that the polymers are as impermeable as impervious clay.

Table II Typical Values of Coefficient of Permeability (cm/sec)

| | |
|---|---|
| Clean Gravel | 1.0 and greater |
| Clean Soarse Sand | 1.0 to 0.01 |
| Sand Mixtures | 0.01 to 0.005 |
| Fine Sand | 0.005 to 0.001 |
| Silty Sand | 0.002 to 0.0001 |
| Silt | 0.0005 to 0.00001 |
| Clay | 0.000001 and smaller |
| Typical Concrete | 0.000001 |
| Polymer Product | 0.0000001 to 0.0000002 |

Despite the impervious nature of the final product it is conceivable that over a long time the polymer will be brought into intimate contact with natural waters including acid rain and acidified ground water. The effect of repeated freeze-thaw cycles over time undoubtedly causes some physical product breakdown. It is therefore desirable to ensure that the pollutants would not leach from the product even under circumstances where the product is fractured into small pieces. To simulate this type of occurence the equilibrium leaching test method was a fine powder and totally immersed in ten times their weight of distilled water which has been acidified by the addition of carbon dioxide. The mixture is held at a temperature of 20° c. and the particles are totally wetted for one hour in a vessel that is magnetically stirred. The water is then separated by emmision spectroscopy, volumetric or colorimetric methods. For pollution by organic constituents standard tests such as Chemical Oxygen Demand can also be carried out on the filtrate.

The percentage of toxicant leached is calculated as a percentage of the toxicant in the final product. The results of equilibrium leaching tests for a variety of industrial wastes are shown in Table III.

TABLE III. EQUILIBRIUM LEACHING TESTS

| Pollutant | Concentration of Pollutant In Waste (ppm) | Concentration of Pollutant In Leachate (ppm) | % Leached |
|---|---|---|---|
| Chromium (Hexavalent) | 25,000 | 0.2 | 0.03 |
| Cooper | 25,000 | 0.26 | 0.03 |
| Nickel | 25,000 | 0.50 | 0.055 |
| Zinc | 55,150 | 0.15 | 0.009 |
| Lead | 101,150 | 0.5 | 0.016 |
| Cadmium | 78,090 | 0.1 | 0.042 |
| Manganese | 45,590 | 0.08 | 0.057 |
| Sulfide | 14,660 | 0.1 | 0.05 |
| Tin | 9,740 | 0.1 | 0.03 |
| Arsenic | 12,500 | 0.16 | 0.03 |

As a result of test work completed in laboratories in the U.K. and the U.S. it was declared that no environmental hazard would be expected from operating the process and disposing of the final product into a land reclamation area.

In addition to safety the stablex product offers a structural integrity that makes it suitable for useful and commercial application such as road base, land reclamation and many others. Studies are currently being conducted to complement the data already accumulated on the product. The objectives of these studies are to obtain complete delisting of the stablex product mainly by the E.P.A. in the U.S.A. In November 1980, Stablex Corporation in the U.S.A. has been granted temporary delisting for stablex product made from 29 industrial wastes.

## THE WASTE MANAGEMENT CONCEPT

Alike most other chemical manufacturing facilities, a stablex operation is highly concerned about proper identification of incoming material, process control, safety and quality assurance. To deal with those concerns, Stablex has imposed themselves a management concept that guides their action.

A facility to treat industrial wastes must be located in an area central to their source to minimize transport costs. It is also important to site the facility adjacent to an acceptable land reclamation area in which the non-toxic final product may be placed. The center must also be located so that transport of wastes to the facility does not have an impact, vehicles entering the facility must be carefully controlled to ensure that needless delays and tie-ups are eliminated. To assure compliance with current environmental regulations there are several steps that must be followed for the successful operation of a Regional Waste Management and Land Reclamation Center. These steps are:

Screening the Waste: Before agreeing to accept a waste material for conversion to inert, synthetic rock at the facility, samples of the candidate wastes are subjected to chemical and physical analysis in a regional laboratory and a waste profile is prepared. Trial formulations are then carried out to determine if the waste can be converted in an acceptable fashion to an environmentally compatible final product. The resultant product is then subjected to one or more nationally recognized standard leachate tests. Only upon successful completion of the above procedures is an agreement to accept the waste completed, delivery scheduled, and a price set. The shipment manifest documents are filled and wastes are transported.

Waste Reception: Wastes are received at the facility in tank trucks, dump trucks, and drum carriers. Wastes are only accepted from duly authorized carriers. On entering the facility, the transport vehicle passes over a weigh scale for determination of delivered waste quantity. A sample of waste is taken for immediate lab analysis to confirm the waste delivered corresponds to the initial waste profile prepared. The in-plant analysis is compared to previous data and manifest documents, and if within an acceptable range, is accepted for treatment. A checklist is then prepared by the plant chemist which ensures that the material has been adequately tested to ensure compatibility with the process.

For bulk liquid deliveries, the truck is directed to an unloading point by the plant operator. The plant operator, having obtained a key, unlocks the proper valve necessary to off-load a tanker insuring the truck is coupled to the proper tank. After discharge, the operator will ensure that the hose connecting the truck to the discharge point is emptied prior to disconnect. At that point the operator closes and locks the receiving valve to insure that no further material may be off-loaded without approval.

In the case of bulk solid delivery, vehicles are directed to specific off-loading bays where material is stored in covered areas.

A similar procedure is followed for drummed wastes. However, after the drums are moved to their storage area, the plant operator indelibly labels each drum with the following information:

..Date received
..Control form number
..Type of material

The entire waste reception area is paved, curbed, and graded to contain any spilled waste. Run-off is directed to a drainage system which discharges to a central sump. Sumped material is introduced to the process to make certain no contaminants are discharged to the environment.

Waste Storage: Liquid wastes are stored in tanks fabricated with appropriate materials. Bulk solid wastes are stored in separate bins which are covered for protection from the elements. Waste received in drums are palletized and stored in a segregated section of the waste reception area.

Pretreatment: Appropriate quantities of compatible liquid waste material are blended in a battery of pre-treatment vessels. Certain materials either from bulk solid waste storage or drum storage are passed through a solids preparation operation to reduce the particle size of the material to the desired specification. Following the size reduction operation, compatible solid waste materials are blended in a large pretreatment tank where appropriate quantities of additives are blended to prepare the mixture for the final product preparation phase. At this point, samples are taken from the pre-treatment facility and tests are run to determine if that batch has the required characteristics necessary to produce satisfactory final product.

Product Preparation: After the plant chemist performs tests to insure the quality of the final material prepared from the pretreatment batch is acceptable, the product preparation run begins. This consists of mixing a weighed quantity of pretreated materials with pre-weighed quantities of additives to produce the final product.

Product Placement: Following completion of the product preparation phase, the product is conveyed, usually by pipeline or truck, to discharge in an adjacent land reclamation placement area. If pipeline placement is not possible, then truck transport is utilized. On setting, the final product, which is a hard rock-like material with a co-efficient of permeability on the order of $10^{-7}$ centimeters per second and with sufficient compressive strength to be suitable for land reclamation use.

Water falling on the placed material tends to run off the surface and is directed to a sedimentation basin where is sampled prior to discharge to insure its environmental compatibility.

The land reclamation material also exhibits other important environmental properties including non-biodegradability, non-flamability, it is unattractive to pests and vermin, and has no odor.

## PUBLIC RELATION EXPERTISE

Good and sound technology, rigorous control and management procedures are not enough. There will be no plant therefore no treatment of industrial wastes, unless citizens are convinced that this plant, located in their community, is advantageous to them.

Siting an industrial waste treatment facility has to deal with the "not in my backyard syndrome", and the images of another love canal nightmare and the Mississauga railroad incident.

By trial and error, Stablex (Canada) Limited found a solution to change the negative perception of a waste treatment plant. We have gained expertise and developed a successful strategy to address the problem of public fear and blind resistance to the installation of our plants.

A combination of proven technology, government support and an effective communication campaign leed to the successful implantation of Stablex in Blainville, 35 miles north of Montreal, Quebec. The M.O.E. of Quebec granted us our permit with the blessing of the citizens, media and of course industry.

The ingredients of our successful communication strategy are: information, consultation, education, participation, time and patience. The figure entitled "Methodology for Change" shows the imput required in order to secure the permits and obtain an approved site, that is supported by the citizens of the region.

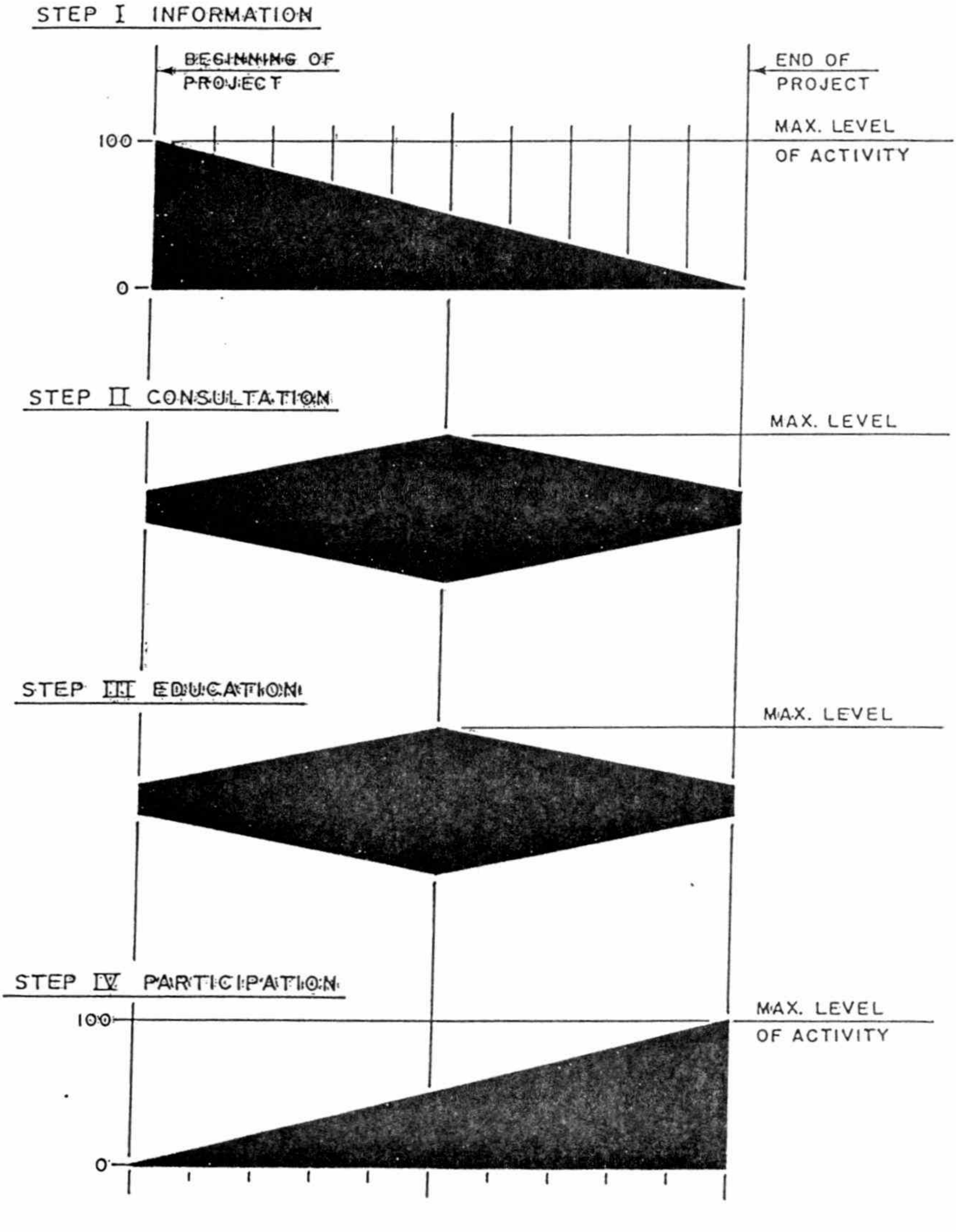
<ins>Information</ins>: This step is the most time consuming. The objectives at that stage are to build your credibility and insure that the message is clear and accurate.

Only after a satisfactory amount of knowledge is absorbed by the majority of citizens will you be ready to proceed.

<ins>Consultation</ins>: This step consist of interacting with the citizens of the community through public meetings and community gatherings for the purpose of obtaining feedback. The information program is assessed at this stage and modifications are made as required.

<ins>Education</ins>: This step recognizes the needs of those with influence in the community, who might be city councillors, reporters or zealous citizens. By satisfying their special needs for facts and knowledge these influential citizens can become your best promotors.

# METHODOLOGY FOR CHANGE



This process of educating the community "influencers" takes place concurrently with the consultation phase discussed previously.

Participation: Participation of well informed citizens and community "influencers" in public hearings, committees and seminars, can result in very helpful suggestions and recommendations. By listening to them and accepting to implement eleven suggestions our company obtained all the public support needed to successfully site a plant in Blainville, near Montreal.

The skills learned in gaining approval and acceptance from the citizens of Blainville will help us to successfully locate and install additional Stablex plants in Canada and in the U.S.A.

## MARKETING PHASE

Although our plant will not be in operation until March 1983, we have already started to define our marketing strategy. The first step, which was to determine the demand for our services, was done a couple of years ago. This study is being updated and refined.

A harsh economic climate has ravaged many of our industries, so it will be difficult for them to absorb a sharp increase in waste disposal costs. Industry must learn to cope with this side effect and ultimately, the cost must be passed on to the consumer.

Stablex will flourish if industry is healthly and legislators enforce their regulation on the quality of the environment. Our belief is that neither government nor industry will take extreme positions so that mutually acceptable standards and targets will be set. We will promote cooperation.

Stablex offers four important benefits to industry:

1) Business enterprises will not be required to make major capital expenditures on waste treatment facilities, instead industry can choose to use our treatment facilities.

2) Stablex assumes the liability once wastes have been transfered to us and accepted by us for processing.

3) Companies will have a convenient and easy method to meet the standard set by the Ministry of the Environment for inorganic waste materials.

4) Easy and quick access to technical service, as well as emergency help to clean up accidential spills and process errors will be at their disposal.

Stablex plans to offer a comprehensive package of services which would include: detailed laboratory analysis of waste, consulting for on-site treatment facilities, in house training of personnel on handling and consolidation of waste products. In addition we could advise on transportation procedures and suitable carriers for specific wastes.

Technical service representatives, lab personnel and even our inside order desk persons will be hired well in advance of our plant start-up. Some training will be carried out at our existing facilities in England and the United States.

## Research and Development

A research and development program will be established on our site as soon as we start operations.

Our priority will be to develop formulations, which can use as raw material, waste products currently going to land fill sites. An example of this is the bag-house dust collected at our local steel plants.

The research team will gather data to declassify stablex material, so that alternative uses can be found for this product.

We have already been approached to resolve some pressing problems that only can be solved with the help of our research team. Undoubtly you will hear more from this group in the years ahead as scientists, unlike us administrators, like to boost about their successes.

## Closing Remarks

Our experience at Stablex (Canada) Limited showed that good, sound and proven technology were not enough to obtain support from the citizens and permit the installation of a Stablex facility.

We embarked on a public education program that dealt principally with safety and aesthetic concerns. Citizens were encouraged to perform their own studies through a committee, and present their findings to the population.

Our dialogue with the citizens continues even though our plant is now being built, because we committed ourselves to keep them informed and interested in our project.

Our Stablex plant will treat a large variety of wastes, but like any technology, it is not a panacea and we do have limitations. We must be assured that our Stablex material can be safely recycled into the environment, so rigorous control procedures will be followed.

Our research and development programs will help develop methods to deal with some of the unique and pressing environmental problems that face us. The research team will investigate alternative uses for the Stablex material once it has been declassified by the Provincial Government.

Stablex Canada's greatest success has been to change people's attitude from strong resistance to the installation of our treatment and disposal facility in their community - to one of being welcome. We are proud of this achievement.

And now, Stablex (Canada) is well prepared to apply this valuable knowledge and experience to the benefit of the provinces that plan to establish regional waste treatment facilities.

# LANDFILL SITES
# OPERATION AND REHABILITATION
# USING
# STEEL INDUSTRY WASTES

by

R. Palombella
Department of Engineering
Regional Municipality of Hamilton-Wentworth
Hamilton, Ontario

## 1. INTRODUCTION

### i) Obsolete Disposal Practices

The establishment and operation of waste disposal sites was traditionally assigned a relatively low priority in the overall scheme of municipal management.

Disposal sites, often justifiably designated "dumps", were usually situated on the outskirts of a town or city, close enough for convenient haulage, but distant enough to avoid creating a public nuisance. Dumps developed almost at random, with garbage being deposited in areas that were considered useless or non-productive. Such areas included swamps, gravel pits and quarries, and, less frequently, stream banks, where refuse would be "washed" away. In this manner, two objectives were met; waste disposal was performed inexpensively, while non-productive areas could be filled and graded to accommodate industrial or recreational activities.

Often, there was little or no regulation of open dumping, resulting in obvious problems such as increased rodent and insect populations, scattered litter, decay, odours, and fire and smoke. In some cases, open burning was performed to extend the useful life of a site of limited size. Fires were caused by smouldering waste delivered to the site, or by vandals who deliberately set fire to exposed garbage. The result of this practice was usually predictable; the burning of damp garbage, often containing tires, created clouds of black smoke that could be seen for miles, with attendant fallout of black particulate matter in the immediate vicinity. Also, there was the constant danger that the fire might spread out of control.

Past practices were generally not a result of negligence or irresponsible management; the accepted methods at that time were considered state-of-the art. These practices continued due to lack of awareness of potential environmental impacts, on the part of regulatory and operating agencies, as well as the general public.

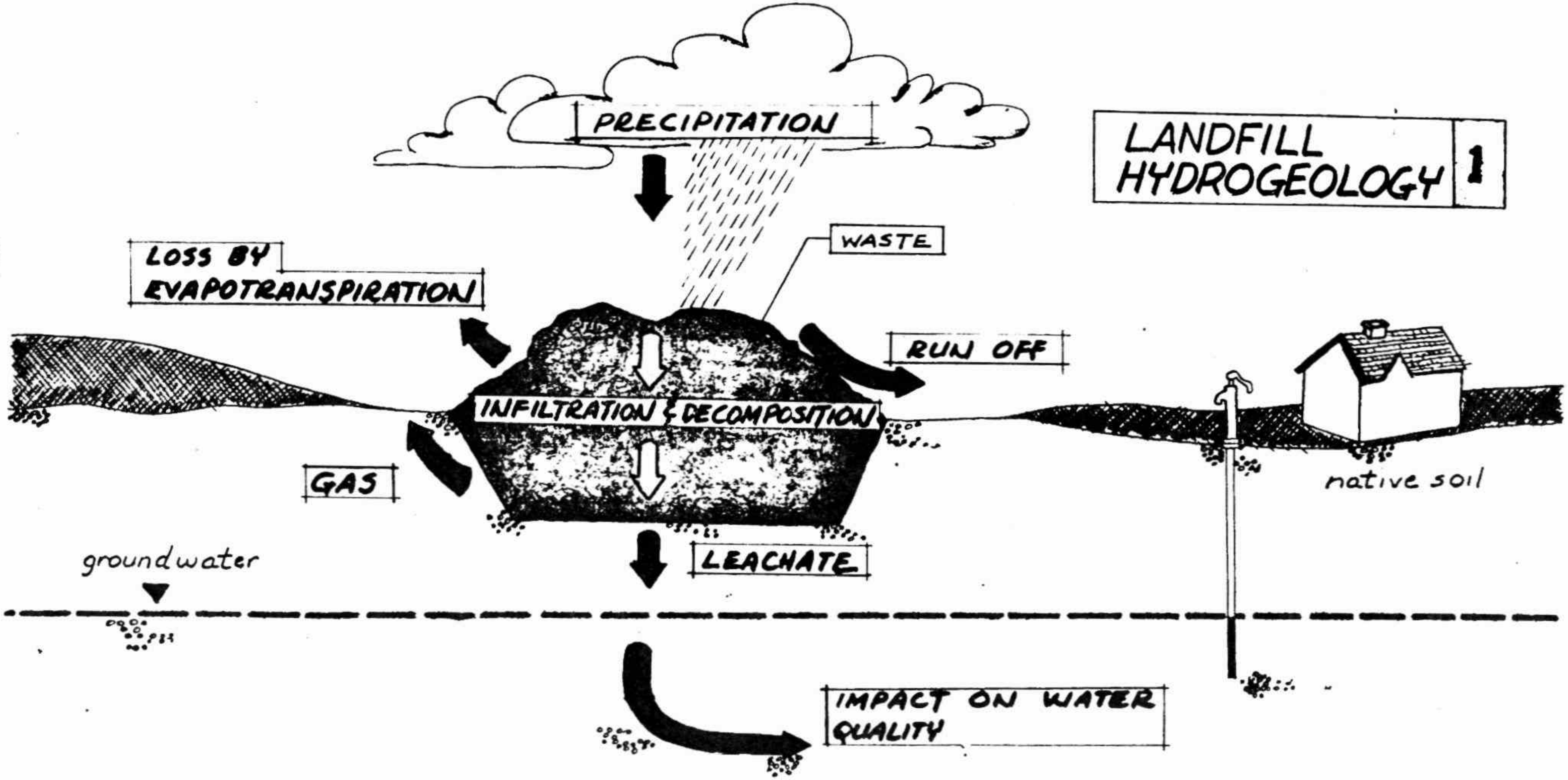
### ii) A New Awareness

The urban growth, increased industrialization, and affluence of the 1950's and 1960's began to take effect. Per capita refuse generation rates escalated, compounded by increasing populations. Intensive industrial expansion added further to the quantity and variety of wastes. Many small dumps grew into large mountains of garbage. All these factors were further augmented by urban expansion, as new building developments approached, and in some cases, surrounded, dumpsites that had existed for up to 30 years.

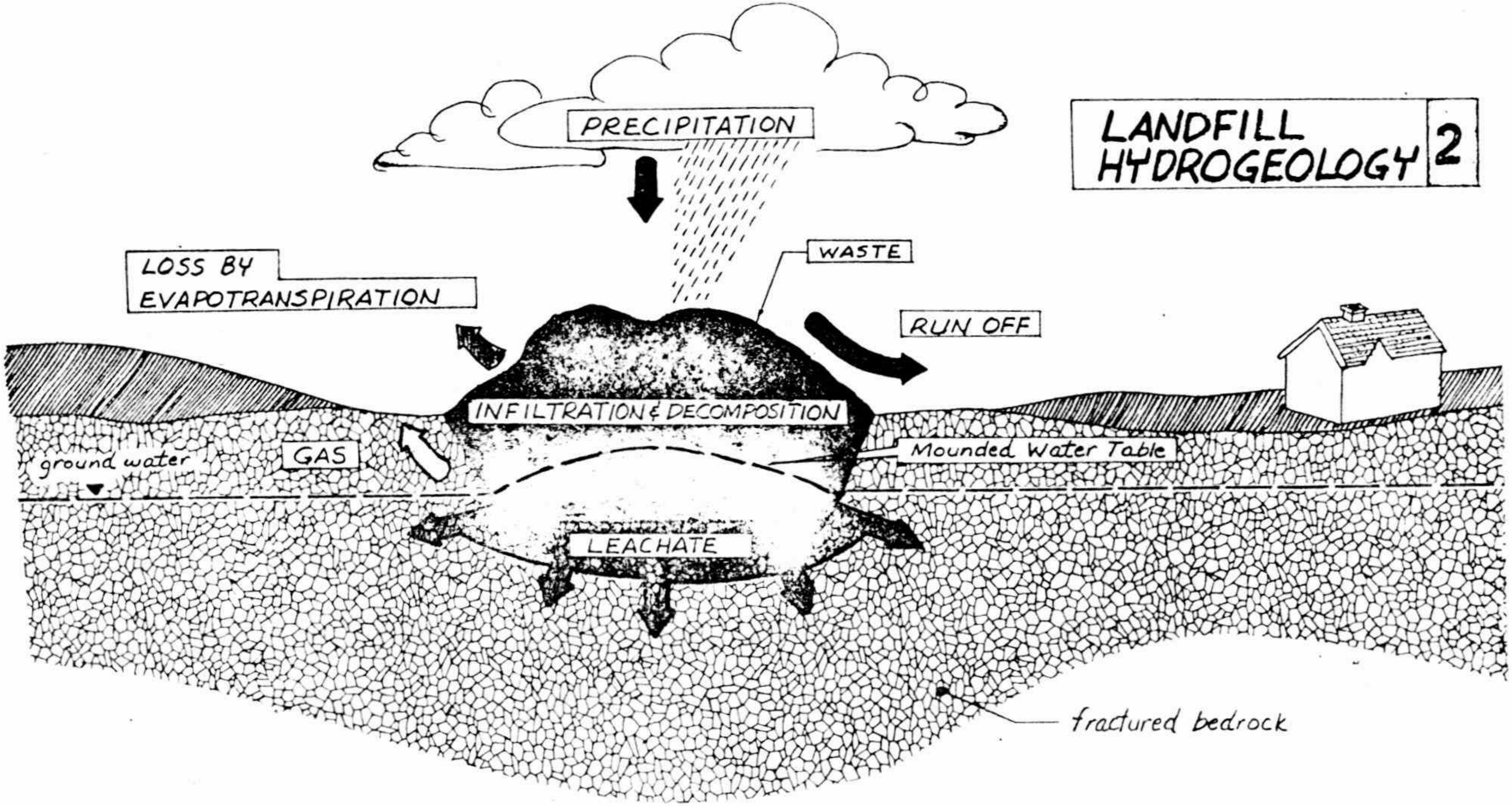
Gradually, the law of mass balance was manifested. Wastes entering disposal sites generated products which mixed with infiltrated surface water. The principal outflows were leachate, the combined result of decomposing waste and surface infiltration, and methane gas, formed by the anaerobic decomposition of putrescible materials. The leachate consisted of numerous elements, including the products of decomposition, complex chemical reactions, and soluble or liquid wastes draining out of the garbage mass.

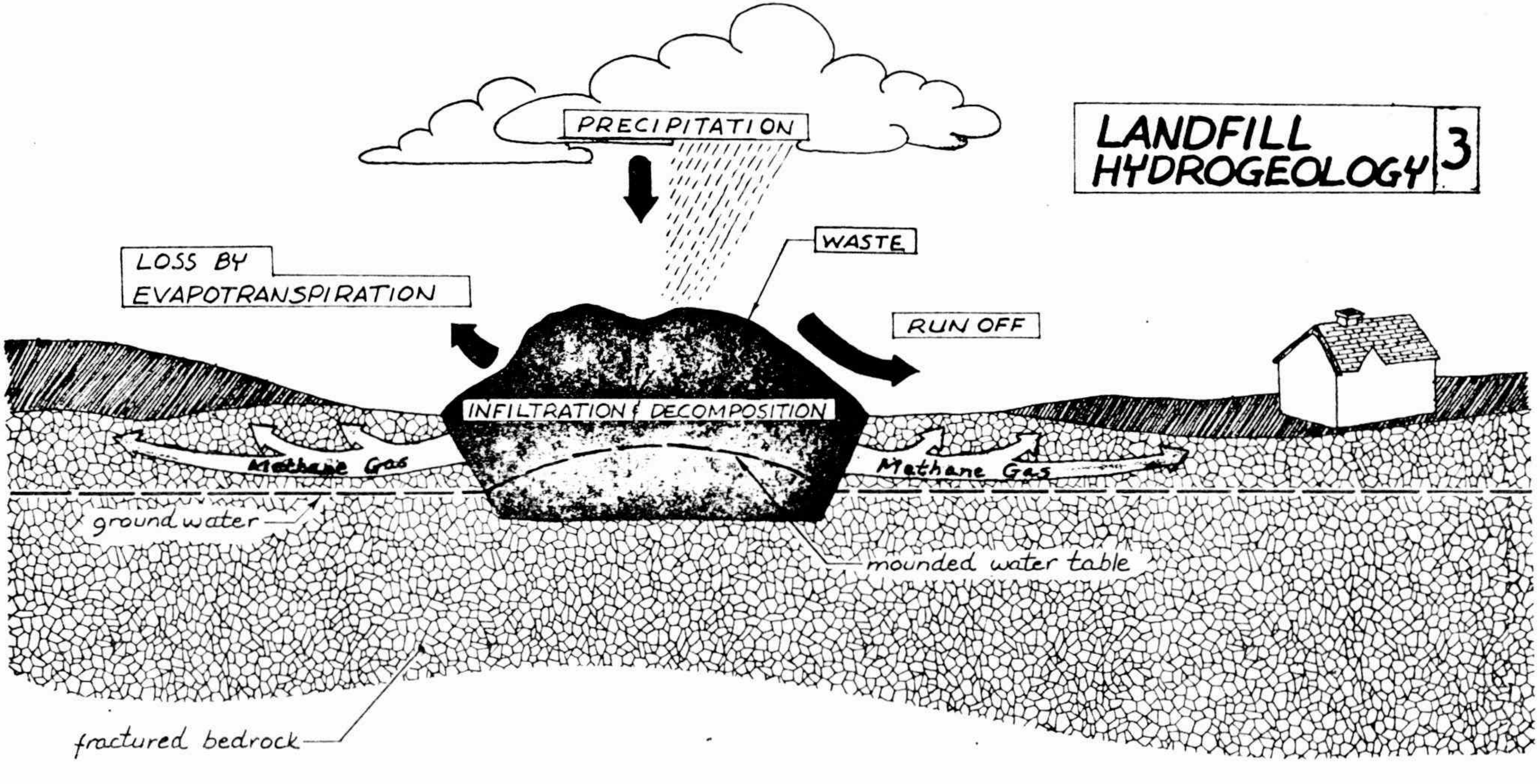
It is now apparent that many sites traditionally selected for waste disposal were, by present engineering standards, at least partly inappropriate. The high water table in wetlands saturates deposited waste and distributes leachate to surface and groundwaters. The porous beds and fissures characteristic of pits and quarries provide ready paths for leachate flow into the groundwater regime, increasing the potential for contamination of underground water supplies. Methane gas from refuse buried below grade in quarries also travels along horizontal rock strata, and there are documented incidents where explosions have occurred in buildings located near garbage disposal sites. The following figures 1, 2 and 3, LANDFILL HYDROGEOLOGY, illustrate these effects.

# LANDFILL HYDROGEOLOGY 1



# LANDFILL HYDROGEOLOGY 2





LANDFILL HYDROGEOLOGY 3

### iii) Contemporary Standards

One of the most significant turning points in waste management occurred in the late 1960's. Prior to this time, garbage disposal practices were regulated mainly under the jurisdiction of the Ministry of Health, with supplementary legislation provided by local municipal by-laws. However, these controls did not specify site development and operating standards, but were in place to deal with reported complaints of nuisance or health hazards.

The responsibility for waste management was transferred among a number of Provincial ministries from 1968 to 1972 when it was finally assigned to the Ministry of the Environment. This latter measure introduced the development of guidelines and regulations for modern waste management practices.

Present Ministry regulations include the following activities:

- operation, development and closure of existing disposal sites
- site selection, development, and operation of new waste handling facilities (i.e. disposal sites, transfer stations, incinerators)

All disposal sites are subject to regular inspections by the Ministry, and those receiving materials other than clean fill require certificates of approval. As a more recent development, Environmental Assessment Hearing procedures have been established. These public hearings are required to evaluate the potential environmental impact of new major projects which may affect the environment, and usually apply to waste processing facilities.

iv) Current Regional System

When the Regional Municipality of Hamilton-Wentworth was established in 1974, it was assigned responsibility for the operation of 10 waste disposal sites. These sites, which had been under the jurisdiction of the Area Municipalities for periods varying from 10 to 30 years, are indicated on Figure 4. As the sites became filled to capacity, they were systematically closed to public use. The last of the former disposal sites closed in October, 1980, when the Region commenced the operation of its new waste management system. The new system consists of the SWARU, an energy from waste incinerator; three modern transfer stations; and a 550 acre landfill site. This site, which is engineered in accordance with the latest standards, is founded on deep impermeable clay, and is self-sufficient in daily and final cover material.

v) Private Disposal Facilities

The closure of former landfill sites led to a new industry in the Region, the establishment of private disposal facilities. The Region's present system does not accommodate materials such as demolition rubble, excavated materials, and bulk industrial solid wastes. Under licence by the Ministry of the Environment, a number of firms have established disposal sites in old quarries, which are approved for landfilling of

# FORMER REGIONAL LANDFILL SITES

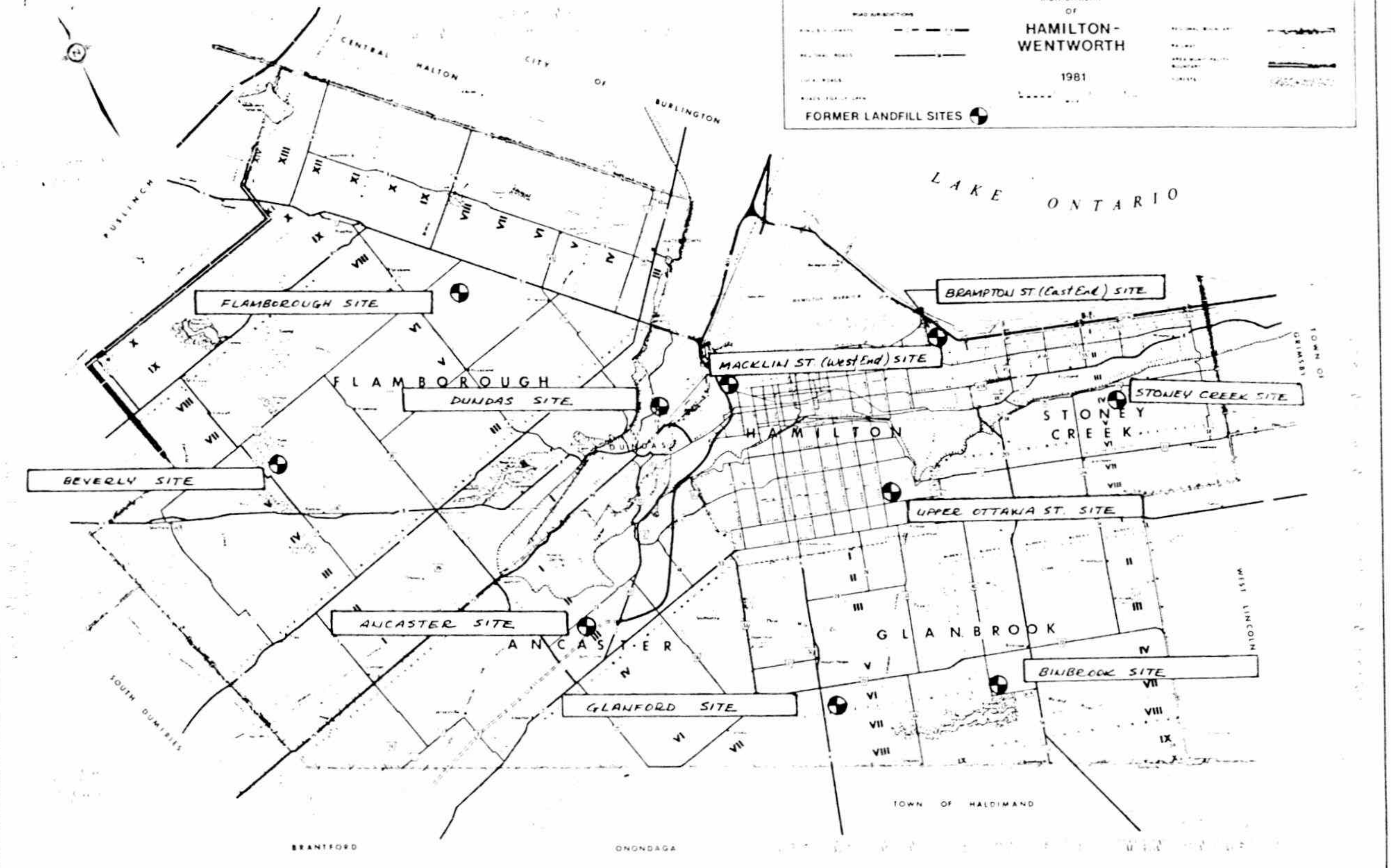


FIGURE No 4

inert rubble and "semi-inert" industrial wastes. This activity diverts a waste stream which would place an unnecessary burden on the costlier Regional disposal system, provides savings to industry in the form of reduced disposal fees, creates additional jobs, and permits rehabilitation of inactive pits and quarries.

The two major private disposal sites in Hamilton-Wentworth are operated by Taro Properties, and Steetley Industries. As a parallel to the Region's disposal system, the local firm of Philip Enterprises has established a transfer station in the Hamilton Industrial core. Various industrial solid wastes are now processed for re-use by other industries, while materials with no further commercial value are transported to the outlying quarries for disposal.

## 2. THE TASK

### i) Preliminary Closure Grading

As the ten former disposal sites were closed to public use, final cover and grading operations commenced.

The first location which was designated for closure is situated in the west end of the Area Municipality of Hamilton. When the Region assumed ownership of this 35 acre site in 1974, the limited remaining disposal space rendered it unsuitable for the disposal of municipal wastes. However, use of the site was continued for the exclusive disposal of inert and "semi-inert" wastes such as construction rubble, tree stumps and surplus excavated soils and roadway bedding. This facility effectively served local needs in this manner for a period of three years. Its central location permitted ready access and economical haulage for various construction projects in downtown Hamilton. As an immediate benefit to the Region, graded construction debris provided stable cover over exposed refuse. Large depressions and ditches accommodated substantial quantities of bulky materials, such as broken concrete, simultaneously; surface ponding, a major cause of leachate generation, was minimized.

However, a relatively impermeable surface cover was required to properly control infiltration.

### ii) Final Cover Requirements

In early 1977 the West Hamilton site ceased receiving rough construction wastes, such as concrete, as the Department of Engineering began final arrangements for suitable closure measures. At that time, this was the first large landfill site in the Region which was to receive final closure grading. Therefore, planning of activities was co-ordinated with the Ministry of the Environment to establish the required criteria to achieve acceptable results.

For final cover operations, the Ministry recommended that a fine-grained material be placed over the top and slopes of the site to a depth of no less than two feet overlain by a layer of clay at least six inches thick. Another lift consisting of six inches of soil of suitable quality to support the growth of vegetation was recommended. All cover materials were to be suitably graded (4% slope) to promote surface runoff and minimize leachate generation. An appropriate vegetative cover, such as grass or dense shrubs would be required as a final measure to control erosion and enhance the finished site appearance.

The Ministry did not specify clay for total cover, but permitted the use of other low-permeability soils or materials, as approved on a site-specific basis.

iii) Availability of Cover Materials

With the initial closure criteria defined, investigations were carried out to determine the availability of suitable cover materials, in order to develop a project schedule. These investigations revealed that adequate conventional cover material could be obtained in two ways. The first scheme relied upon the intermittent supply of surplus excavated materials from local construction projects. However, these supplies were normally inconsistent and unassured, often containing variable quantities of large undesirable components such as broken rocks and concrete. Reliance upon these sources would render the scheduling of work activities and site equipment difficult and uneconomical.

The alternate conventional plan would have required tenders for the supply and grading of cover materials. The supply of approximately 250 000 cubic yards of interim cover, and a topping of 250 000 cubic yards of clay for the West Hamilton Site would have cost about $2.00 per cubic yard, for a total of $1 000 000. This figure is based upon 1977 costs, while the equivalent present value would be in the order of $1 500 000

Because of the massive cost of the latter plan, it was initially decided to pursue the first option. However, it became apparent late in 1977 that, due to diminishing construction activities, excavated fill could not be obtained in sufficient volumes to carry out a sustained programme of closure.

## 3. THE OPPORTUNITY

In 1976, the Region had commenced a trial programme, with the assistance of DOFASCO Inc. to evaluate the suitability of S.I.W. (Steel Industry Wastes) for landfill site daily cover, slope topping, and intermediate cell cover. Until that time, the majority of cover materials for daily operations consisted of local contractors' surplus excavated fills, whenever available. Because disposal site space restrictions prevented stockpiling for year-round use, low-grade quarry strippings were purchased for cover when free fill was unavailable. As the available quantity, and continuity of supply of S.I.W. became a ready commodity, the advantages of this material became apparent.

Therefore, DOFASCO S.I.W., which previously had been used primarily as daily cover at operational disposal sites, was selected for trials at the West Hamilton Site.

## 4. THE EVALUATION

During the initial field trials of S.I.W. as site cover, investigations were carried out by the Department of Engineering and the Ministry of the Environment. Preliminary work included examination of the processes generating the various materials incorporated in S.I.W., accompanied by chemical analyses to verify their environmental acceptability.

A summary of the components in S.I.W. is provided in Table 1.

TABLE 1

S.I.W. COMPONENTS SUMMARY

| | GENERAL DESCRIPTION | % OF TOTAL MIX |
|---|---|---|
| 1 | Solidified Oxygen Steel-making Oxides | 60 |
| 2 | Excavation, Dredgings & Refractory Rubble | 15 |
| 3 | Slag Fines | 15 |
| 4 | Foundry Sand | 7 |
| 5 | Miscellaneous: Sweepings, Baghouse Dust | 3 |
| | TOTAL | 100% |

During the early work with S.I.W., the term "Foundry Sand" was used to describe the general range of industrial materials under study. In fact, the actual proportion of foundry sand was about 7% of the total mix. For purposes of accuracy, the more representative term "Steel Industry Waste" (S.I.W.) replaced the previous designation.

Individual samples of these wastes were obtained at DOFASCO by Regional staff, as were mixed samples arriving at the landfill sites during subsequent placement. Leaching tests for blended S.I.W. were performed by the Regional and DOFASCO laboratories. Analytical results, reviewed by the Ministry of the Environment, provided the following observations:

a) Leached washwater meets the Ministry's Drinking Water Criteria, with the exception of lead and phenol. The concentrations of the latter two materials are not considered detrimental in a disposal site setting, and all leached elements are well within Ministry of the Environment irrigation water standards.

Lead-leachate content of the individual components, as well as the current S.I.W. mix is within Ministry of the Environment drinking water guidelines.

b) The S.I.W. mix is highly alkaline (pH=12), due primarily to calcium hydroxide. This feature is desirable because high initial pH is effective in immobilizing metal leaching. Weathering due to atmospheric carbon dioxide will gradually neutralize the alkalinity, while restricting the movement of heavy metals by converting them to carbonates.

c) Low permeability (approximately $10^{-6}$ cm/sec.) minimizes infiltration, thereby restricting leaching of phenols, which will undergo gradual biological degradation.

d) High pH levels initially inhibit vegetation growth, but after 1 to 1½ years of weathering, and neutralization, annual weeds take root and thrive in this material. After two growing seasons, the thatch formed by dead weeds has added sufficient organic material to the ground surface to support alternate vegetation.

Work performed by Dr. J. Emery of the Trow Group Consultants revealed that various DOFASCO wastes could be blended to create a material which was more suitable for disposal site operations and cover. The optimum conditions to achieve a coefficient of permeability in the order of $10^{-6}$ cm/sec. were defined as:

-23.7% (total weight) moisture
-Standard Proctor Maximum Dry Density of 86.7 pcf
-use of standard compaction methods for cohesive soils (i.e. vibratory sheepsfoot roller) to achieve 95% Standard Proctor Maximum Density

The permeability noted above is in the poorly permeable to practically impervious range, comparing favourably with low-permeability clays.

The Ministry of the Environment Regional Office subsequently approved S.I.W. for landfill use, provided that it was not deposited in the immediate vicinity of water supply wells.

## 5. THE IMPLEMENTATION

### i) Application

The preliminary rough grading of this site proceeded from late 1977 into early 1979, utilizing approximately 300 000 cubic yards of S.I.W. Early S.I.W. blends consisted mainly of solidified oxides from available DOFASCO stockpiles.

Approved S.I.W. was sometimes obtained from other local industries, but materials from DOFASCO represented the major fraction, constituting more than 95% of the total.

Satisfactory placement of final cover was achieved by grading accompanied by continuous passes with large bulldozers (D9 or equivalent) to create a relatively continuous and integral layer of nearly impervious cover. Although the compaction achieved was less than optimum, two compensating factors were present. First, laboratory tests indicated that the permeability of S.I.W. decreased as curing time increased.

Second, the in-place height of the S.I.W. cover lift was four to six feet, or two to three times thicker than the Ministry guideline of two feet for relatively impervious material. Figure 5 illustrates typical in-place final cover.

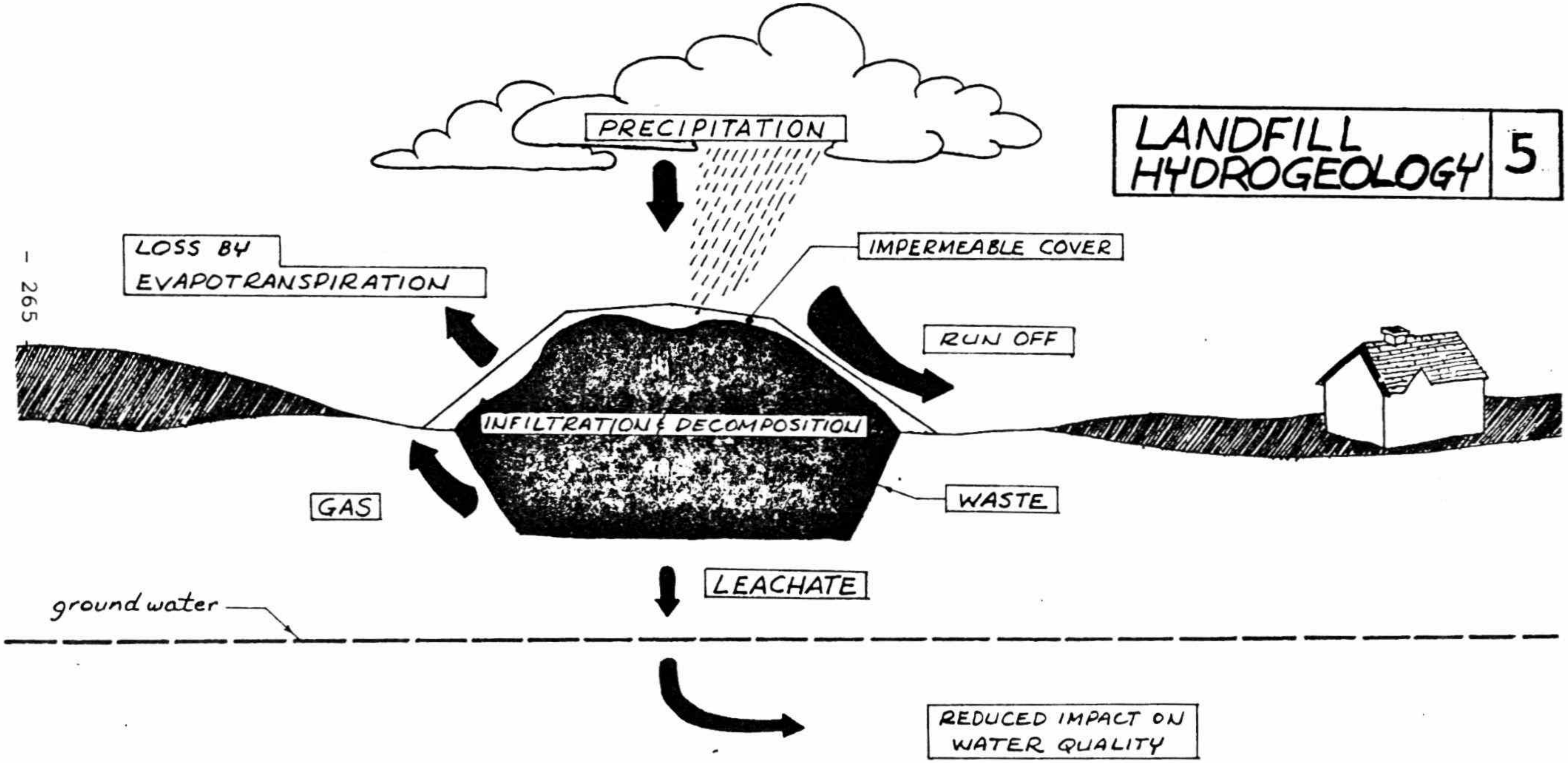

LANDFILL HYDROGEOLOGY
5
PRECIPITATION
LOSS BY EVAPOTRANSPIRATION
IMPERMEABLE COVER
RUN OFF
INFILTRATION & DECOMPOSITION
GAS
WASTE
LEACHATE
ground water
REDUCED IMPACT ON WATER QUALITY

TABLE 2

SUMMARY OF S.I.W. APPLICATIONS

| Site | Estimated Quantity (cubic yards) | Estimated Unit Value $/cubic yard | Estimated Saving |
|---|---|---|---|
| Upper Ottawa Street | 700 000 | $2.00<br>(1977-1982) | $ 500 000 |
| West Hamilton | 275 000 | $2.00<br>(1977-1980) | $1 400 000 |
| Ancaster | 80 000 | $2.50<br>(1977-1982) | $ 200 000 |
| Stoney Creek | 60 000 | $2.50<br>(1980-1982) | $ 150 000 |
| Various Other | 50 000 | $2.50<br>(1979-1981) | $ 125 000 |
| TOTAL | 1 165 000 | | $ 2 425 000 |

The estimated quantities and unit costs noted above are conservative values, based upon equivalent haulage costs for surplus fill. This calculation assumes an adequate supply of surplus material. The equivalent purchase value of excavated cover material delivered to sites, is approximately double the above amounts ($5/cubic yard or $5 000 000).

sludge would have flowed down the side slopes, affecting the off-site perimeter.

The S.I.W. sludge mix was spread over the top of the site to cover exposed refuse and provide a growth medium for native vegetation. The balance of the sludge was landfilled at the Upper Ottawa Street Landfill Site (12 000 cubic yards) and the Ancaster Landfill Site (3000 cubic yards). The use of S.I.W. at the Brampton Street site resulted in substantial savings for the plant expansion project by eliminating a round-trip haul of 18 miles to the Upper Ottawa Street Site for approximately 1000 loads of sludge. Field equipment and site supervision at the Brampton Street location were provided by DOFASCO at no cost to the Region. The Region's total estimated saving associated with this scheme was approximately $25 000.

## 7. THE SAVINGS

Table 2 summarizes the quantity of S.I.W. used by the Region since 1976, and the associated savings.

subsequent cell lifts. This measure is necessary to prevent the formation of perched leachate pockets, and the development of future leachate springs on side slopes.

Also, impermeable cover will reduce or eliminate methane gas exfiltration from the immediate site surface. Therefore, it is particularly important to provide gas monitors outside the perimeter for early detection of methane migration, should it occur. Porous soils around a site will generally permit dispersion of gas to the atmosphere, while fractured bedrock may transmit gas to structures beyond the site. In winter, the surface of porous soils may freeze and trap gas, resulting in lateral migration. If necessary, methane control devices can be installed during, or after, site closure.

## 6. SEWAGE SLUDGE STABILIZATION

In 1978, DOFASCO S.I.W. was used in another unique application to stabilize digested sewage sludge. At that time, the proposed expansion of the Regional Sewage Treatment Plant in Hamilton required the excavation, removal and disposal of 24 000 cubic yards of inactive digested sewage sludge which had been buried on the plant property several years before. Ten thousand cubic yards of excavated sludge were blended with S.I.W. at the Brampton Street landfill site, adjacent to the Sewage Treatment Plant. Stabilization of the sludge was required because of the limited space remaining at this disposal site. Otherwise, the semi-liquid the Region's field trials revealed that an eighteen month period of weathering resulted in sufficient atmospheric neutralization to allow the growth of naturally occurring vegetation. In general, a one or two year growth of indigenous plants should supply adequate organic content to the ground surface to permit the application and growth of cultivated vegetation.

Progressive plant growth serves to "bind" the surface, and prevent dusting. However, a top dressing (6 inches) of clay was recommended by the Ministry of the Environment in order to minimize the immediate potential for wind-borne dust. Seed mixes are available for hydro-seeding of clay, but the proposed recreational use of the West Hamilton site prompted a decision to apply topsoil for early grass growth. Hence, although the DOFASCO S.I.W. exhibited most, or all of the qualities required of "final cover" it was used as "intermediate cover" in the Region's applications. Nonetheless, this material represented the most significant component of the site closure operations, due to the quantity available and its field performance.

Depending upon scheduling of the proposed site use, the feasibility of permitting natural conditioning, versus application of topsoil, must be evaluated on a site-specific basis.

A low-permeability cover minimizes surface water infiltration and gradually diminishes sub-surface leachate flow and surface leachate springs. If relatively impermeable materials are used for daily operations, underlying cells should be partially stripped of cover before the placement of

Steel Industry Wastes were subsequently used in the operation and closure of four major sites, the Upper Ottawa, West End, and Brampton Street sites in Hamilton, and the Jerseyville Road site in Ancaster.

On larger sites, S.I.W. was delivered by 40 cubic yard dump-trailer trucks. In smaller, more restricted areas, tandem axle dump trucks were employed for haulage.

Operations were normally carried out during favourable weather, and were suspended during the wet months of the spring and fall when site accessibility became extremely difficult. Similarly, winter activities were restricted due to difficulties encountered in spreading, grading, and compacting partially frozen fill over snow-covered ground.

In late 1979, no further grading was performed at the West Hamilton site while the closure status of all operational and closed Regional disposal sites was reviewed. A proposed final closure schedule was prepared in mid-1980. Comprehensive closure activities included hydrogeological investigations of all Regional disposal sites.

ii) Observations

In-place S.I.W. normally remains in a firm, stable condition, exhibiting slight cementitious characteristics, unless disturbed by heavy machinery.

Preliminary horticultural analyses indicated that S.I.W. appeared to have no vegetation support capabilities, however,

## 8. SUPPLEMENTARY CLOSURE ACTIVITIES

Hydrogeological consultants were commissioned to perform initial environmental monitoring at former Regional disposal sites, as part of general closure operations. The results obtained from this work identified the essential accessory measures required to achieve safe closure, and to satisfy Ministry of the Environment guidelines.

The Region has further assumed the responsibility to perform ongoing hydrogeological monitoring at all closed sites. This comprehensive program, which includes regular field sampling and laboratory analyses, provides a continuous record of the presence and impact, if any, of leachate and methane gas migration. In this manner, potential problems can be identified and remedied expeditiously. It is generally expected that the closed sites effect on the environment will diminish with time, but Regional monitoring will continue for as long as recommended by the Ministry.

When all closure measures have been completed in accordance with Ministry requirements, it is expected that site ownership will be returned to the appropriate local municipality. If further environmental protection measures (i.e. leachate or gas collection systems) are necessary, these will be implemented before transfer of site ownership. This work has generally been completed where required.

## 9. SUMMARY

This presentation has provided a case history description of a unique application for a specific industrial waste, focusing on one aspect of the Region's overall waste management program.

Note that the term "waste management" is used rather than "waste disposal". The dictionary definition for "waste" includes "to spend or use carelessly, squander; to allow to be used inefficiently; not productive; discarded as worthless". A contemporary waste handling system must process refuse safely and efficiently, and if possible, exploit the resource potential of refuse materials for maximum benefits. In particular, the current economic climate, increased scrutiny of public sector works, and the mandate to "do more with less, necessitate the application of innovative practices to minimize the "waste" in "waste disposal".

The activities described reflect a growing effort to use waste as a resource. Private industry has, for many years, recycled its by-products, and present conditions require that innovative thought be further extended to devise new applications, or outlets, for waste products also.

The use of S.I.W. has resulted in mutual benefits to both the Region and local industry by providing low-cost disposal for the private sector, while assuring a reliable source of suitable landfill site cover.

The Region of Hamilton-Wentworth has completed its present task of site closures at minimal cost, by having access to cover material which would otherwise be imported at substantial cost. Although the Region will not require the use of S.I.W. in the foreseeable future, the generation of industrial and construction wastes continues.

In communities where conventional disposal site cover materials are scarce or costly, it is worthwhile to investigate available options.

Thorough evaluations, performed with the assistance of the Ministry of the Environment, must first be carried out to determine whether or not a proposed material is acceptable for a specific application.

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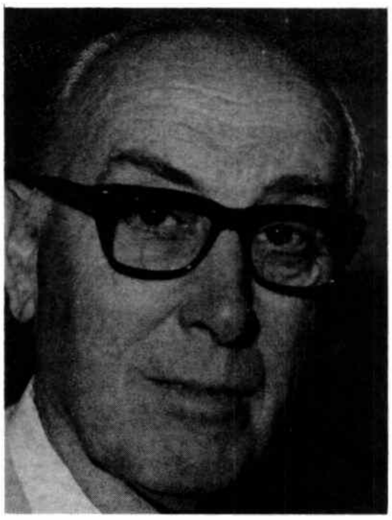
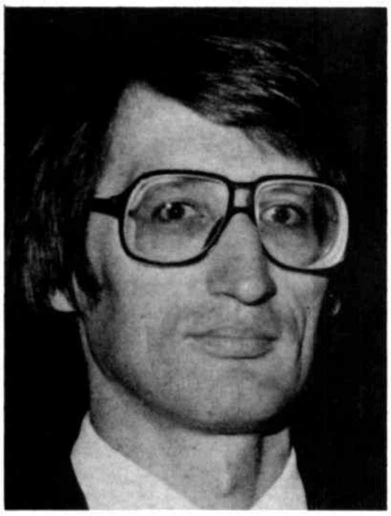
## ACKNOWLEDGEMENTS

I wish to express my appreciation to Val Terluk, C. E. T., for his assistance in the preparation of this paper.

# SESSION V - AIR QUALITY



**Chairman:** T. W. Cross, Director
Environmental Approvals Branch
Ontario Ministry of the Environment
Toronto, Ontario



M. Sabanski
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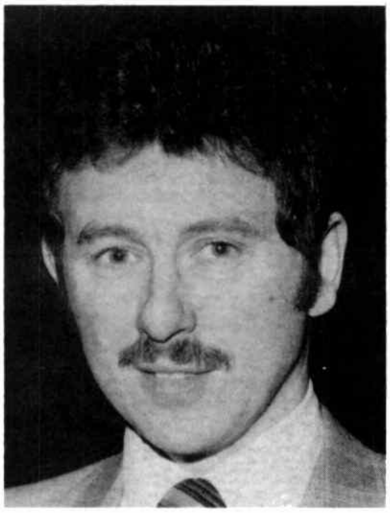
Rexdale, Ontario



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# ABSTRACT

## $SO_2$ Scrubbing Using Limestone

by

M. Sabanski, Acres,Davy,McKee Ltd.
Toronto, Ontario

In 1974, Davy S-H introduced a highly efficient sulfur dioxide scrubbing process which has a lime solution as the active reagent. The final product from all Davy S-H processes is environmentally inert gypsum.

Since its introduction, the Davy S-H process has proven to be highly reliable and efficient. In addition, chlorides have been demonstrated to enhance the process, and no problems due to plugging or scaling have been reported.

Davy S-H now reports the commercial availability of two variations on the lime solution process: the wet/dry hybrid, and the limestone slurry process.

The wet/dry hybrid incorporates the best features of both wet and dry lime scrubbing to effectively solve the re-heat problem. The temperature of the treated effluent gases is sufficiently high for direct discharge to the atmosphere without additional heating. In addition, the unit retains a high degree of efficiency both with respect to sulfur dioxide scrubbing and lime utilization.

The limestone process applies a limestone slurry as the scrubbing medium. Through the highly effective utilization of recycle streams, both the efficiency of sulfur dioxide scrubbing and the utilization of limestone is maximized. The final product from this process is environmentally inert gypsum.

Note: A formal text of this paper was not made available by the author for inclusion in these Proceedings.

# HAZARDOUS WASTE DISPOSAL BY THERMAL OXIDATION

by

J. Young, John Zink Company, Tulsa, Oklahoma.

## INCINERATOR PRIME OBJECTIVE SAFE, EFFECTIVE DISPOSAL OF INDUSTRIAL WASTES

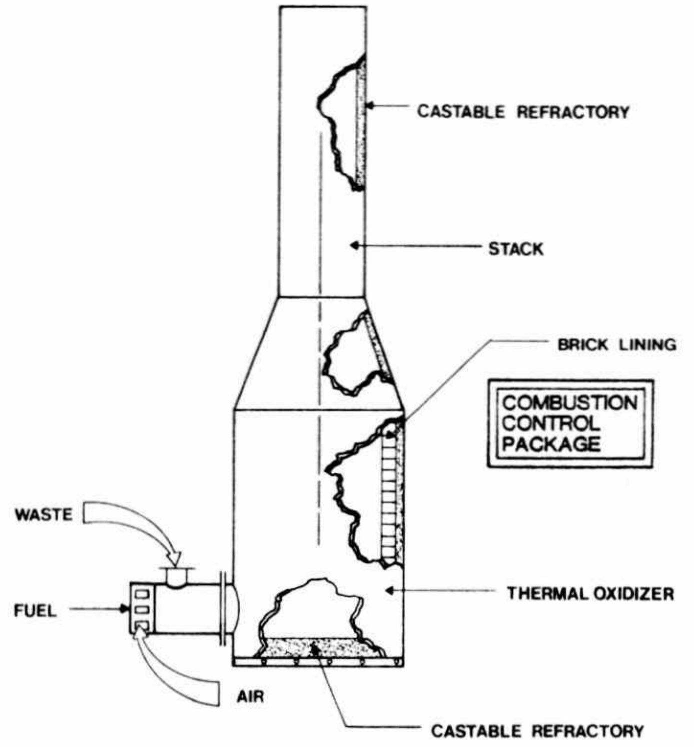


FIGURE A-BASIC INCINERATION SYSTEM

Incineration has proved to be a viable method for the disposal of hazardous wastes. This is evidenced by the fact that John Zink has in excess of 600 incineration systems in service throughout the world, destroying a wide array of hazardous wastes.

The basic incineration system is shown schematically in Figure A. It consists of an incinerator or Thermal Oxidizer (T.O.) as we prefer to call it, burner, stack and combustion control package. The Thermal Oxidizer is a cylindrical steel vessel with the walls normally lined with fire brick and the floor normally lined with castable refractory. The stack is cylindrical in shape and normally lined with castable refractory.

**PRODUCTS OF COMBUSTION**

**IDEAL**

$$\underbrace{CO_2, H_2O, O_2, N_2,}_{FG} NO_{XA}{}^{*}; SO_{XA}{}^{*}$$

**REAL**

$$CO_2, H_2O, O_2, N_2, \quad NO_X, SO_X$$

$$UHC, CO$$

* – Sub A designates acceptable level.

The ideal composition of the flue gas (FG) resulting from the high temperature oxidation of hydrocarbons by the basic system is $CO_2$, $H_2O$, $O_2$, $N_2$, and acceptable levels of $NO_x$ and $SO_x$. During this presentation acceptable levels of $NO_x$ and $SO_x$ are denoted by a sub A. The real composition of the flue gas from a commercial system contains low concentrations of CO and unburned hydrocarbons (UHC) in addition to $CO_2$, $H_2O$, $O_2$ and $N_2$.

The Clean Air and Resource Conservation and Recovery Act (RCRA) which governs the amount of inorganic acids ($SO_x$, $NO_x$, $Cl_2/HCl$, +) and particulate ($P_2O_5$, $Al_2O_3$, NaCl, +) and the rapid increase in the cost of energy, have limited the applicability of the basic Thermal Oxidizer system. Currently, an optimum pollution control process is one which either minimizes fuel usage or maximizes energy recovery while converting an industrial waste into an environmentally acceptable form.

Meeting CO and UHC regulations is accomplished by the correct selection of T.O. residence **T**ime, operating **T**emperature and **T**urbulence: the 3 T(s). Figure B is a plot of residence time versus carbon monoxide and hydrocarbon destruction efficiency. It shows that CO and hydrocarbon destruction efficiency increases as residence time and operating temperature increase.

Figure C is an example of how this information is used to determine concentrations of UHC and CO in the flue gas. This problem is burning methane with 25% excess air in a horizontal T.O. Having a residence time of 1.0 seconds and an operating temperature of $T_2$. Air injected into the T.O. in addition to the 25% excess air is used to lower the methane's 3200°F adiabatic temperature to $T_2$.

The destruction efficiency obtained from the graph for CO and HC is 99.88% and 99.985%, respectively. The heat and mass balance calculation determine flue gas concentration for unburned hydrocarbon [CH4] and carbon monoxide [CO] of 7.1 and 56.8 ppmv, respectively, on a dry basis.

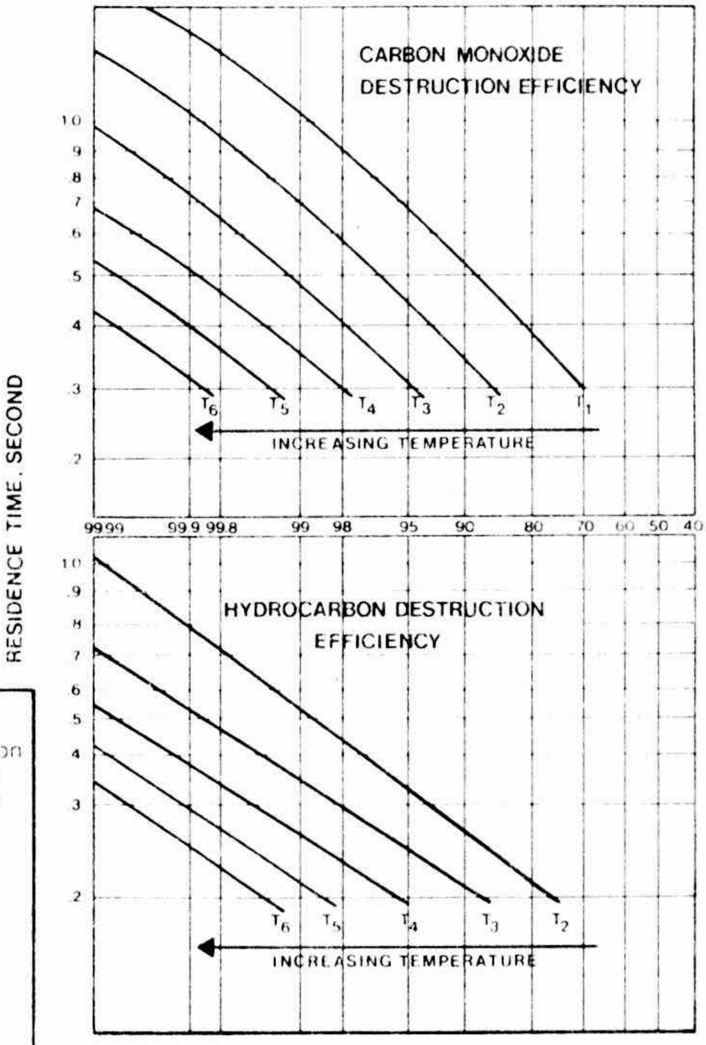
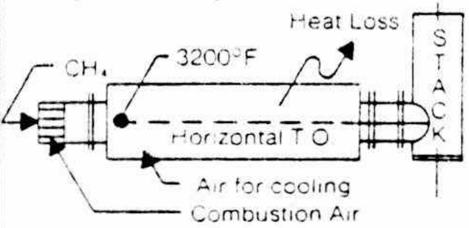


FIGURE B - DISTRUCTION EFFICIENCY

EXAMPLE

What is the concentration of CO and unburned hydrocarbon in the flue gas when the residence time is 1.0 second and the operating temperature is $T_2$? Use air to cool operating temperature to $T_2$

- CO graph reading = 99.88%
- HC graph reading = 99.985%



Basis 1 mole of $CH_4$

$$CH_4 + 2O_2 \rightarrow CO_2 + 2\,H_2O$$

Stoichiometric Air = 9.52 (2/.21)
125% air (Burner) = 11.90 (9.52 × 1.25)
Flue Gas: $N_2$ = 9.40 (11.9 × .79)
$O_2$ = 0.50 (11.9 × 9.52) .21

Flue Gas @ 3200°F (Figure D)
$CO_2$ = 1
$H_2O$ = 2
$N_2$ = 9.4
$O_2$ = 0.5

Assume after subtracting heat loss 12 moles of air will cool flue gas to $T_2$

Flue gas @ $T_2$
$CO_2$ = 1
$H_2O$ = 2
$N_2$ = 18.88 (9.4 + 12 × .79)
$O_2$ = 1.26 (0.5 + 12 × .21)
$CH_4$ = $1.5 \times 10^{-4}$ 1(1-.99985)
CO = $1.2 \times 10^{-3}$ 1(1-.9988)
Total dry flue gas = 21.14 moles
[$CH_4$] = 7.1 ppmv dry basis
[CO] = 56.8 ppmv dry basis

FIGURE C - EXAMPLE PROBLEM

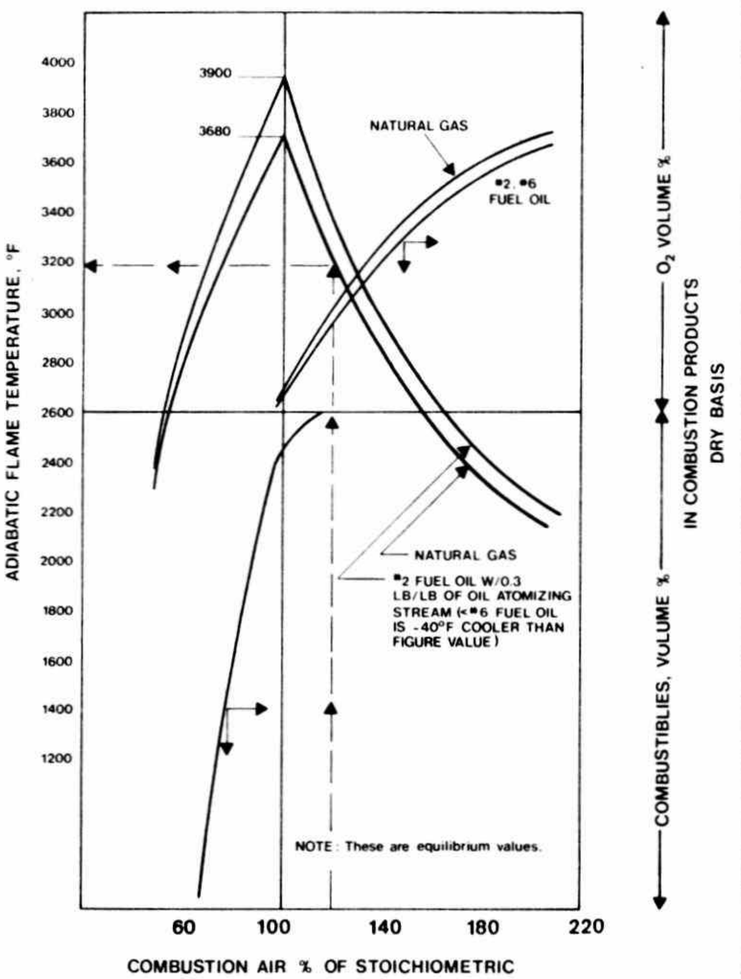


FIGURE C - FLAME TEMPERATURE

In this analysis the flame temperature was indicated to be 3200°F. Figure D is a plot of adiabatic flame temperature, volume percent combustibles and volume percent oxygen versus percent of stoichiometric combustion air for #2 fuel oil and natural gas. The figure indicates a theoretical flame temperature of 3200°F when methane is burned with 125 percent of stoichiometric combustion air (25% excess). In the example, air was used to cool the 3200°F products of combustion leaving the burner to the Thermal Oxidizer exit temperature of $T_2$.

## TABLE I
## INDUSTRIAL WASTE AND POLLUTION PROCESS

| Classification | Industrial Waste | Pollutant | Process Number |
|---|---|---|---|
| Gas | Asphalt fumes | | 1.1, 1.2, 1.3, 1.4 |
| | Chloroform | $Cl_2$/HCl | 2.1, 2.2 |
| | Hydrocarbon fume | | 1.1, 1.2, 1.3, 1.4 |
| | HCN + $H_2$ | $NO_X$ | 3.0 |
| | $H_2S$ Vents | $SO_X$ | 2.1, 2.2 |
| | Methyl Chloride | $Cl_2$/HCl | 2.1, 2.2 |
| | $NH_3$ | $NO_X$ | 3.0 |
| | $NO_X$ | $NO_X$ | 3.0 |
| | Phosgene | $Cl_2$/HCl | 2.1, 2.2 |
| | Tail Gas | | 1.1, 1.2, 1.3, 1.4 |
| | VCM Vents | $Cl_2$/HCl | 2.1, 2.2 |
| Gas/Solid | Air/Maleic Anhydride | | 1.1, 1.2, 1.4 |
| | Air/Phthalic Anhydride | | 1.1, 1.2, 1.4 |
| | Air/Polyethylene | | 6.1, 6.2, 6.3 |
| | CO + $H_2$/C | | 6.1, 6.2, 6.3 |
| | CO + $H_2$/C + Ash | Particulate | 7.1, 7.2 |
| | Hydrocarbon/C + Ash | Particulate | 7.1, 7.2 |
| | Propene/$Al_2O_3$ | Particulate | 5.1, 5.2, 5.3 |
| Liquid | Acrylonitrile | $NO_X$ | 3.0 |
| | Carbon Tetrachloride | $Cl_2$/HCl | 2.1, 2.2 |
| | Chloroamine | $Cl_2$HCl, $NO_X$ | 4 |
| | Herbicides | $Cl_2$HCl | 2.1, 2.2 |
| | Hexachlorobenzene | $Cl_2$/HCl | 2.1, 2.2 |
| | Hydrazine | $NO_X$ | 3.0 |
| | $H_2O$ + Creosote | | 1.1, 1.2, 1.4 |
| | $H_2O$ + Iso-cynates | | 1.1, 1.2, 1.4 |
| | Nitrosamine | $NO_X$ | 3.0 |
| | Organic Acids | | 1.1, 1.2, 1.4 |
| | Pesticides | $Cl_2$/HCl | 2.1, 2.2 |
| | PCB | $Cl_2$/HCl | 2.1, 2.2 |
| | Pyridine | $NO_X$ | 3.0 |
| | VCM | $Cl_2$/HCl | 2.1, 2.2 |
| | High $N_2$ Crude | $NO_X$ | 10.0 |
| Liquid/Solid | APP + Solvent/Catalyst | Particulate | 5.1, 5.2, 5.3 |
| | Biosludge | Particulate | 5.1, 5.2, 5.3 |
| | Dye Solution | Particulate | 5.1, 5.2, 5.3 |
| | Melamine Slurry | $NO_X$ | 8.0 |
| | Phosphorous Sludge | $H_3PO_4$ | 5.1 |
| | Salt Solution | Particulate | 5.1, 5.2, 5.3 |
| | TPA/Catalyst | Particulate | 5.1, 5.2, 5.3 |
| | Polypropylene/Catalyst | | |
| Solids | APP/Catalyst | Particulate | 9.0 |
| | Coal Fines | Particulate | 7.1, 7.2 |
| | Coke Fines | Particulate | 7.1, 7.2 |
| | DNT Cellulose | $NO_X$ | 8.0 |
| | Polyethylene | | 6.1, 6.2, 6.3 |
| | Sodium Organic Salts | Particulate | 7.1, 7.2 |
| | Wood Chips | Particulate | 7.1, 7.2 |

Table I entitled Industrial Waste and Pollution Process lists these categories in the left hand column. Note, the absence of a gas + liquid category. A gas + liquid waste, both fluids, versus a gas only or liquid only waste requires a choice of burner and not process.

The middle column lists a typical waste for each category. For example, a fume stream which is predominately air containing approximately one percent (10,000 PPMv) hydrocarbon is listed as a gas waste and biosludge is listed as a liquid + solid waste. Obviously, this second column does not contain all known industrial wastes. However, it is hoped that your waste is sufficiently similar to a waste listed so you can choose the correct waste process.

Meeting stringent pollution control regulations governing the amount of inorganic acids, ($SO_x$, $NO_x$, $H_3PO_4$, $CL_2/HCL$) and particulate matter requires the use of additional equipment with the basic incineration system. A majority of the remaining portion of this paper is dedicated to furnishing the reader with a method of selecting the correct system. To accomplish this task, it was necessary to place this selection scheme on a "Cookbook" basis by dividing the various industrial wastes into an "As Received" classification and then specifying the applicable process.

Wastes are supplied to a disposal process in the form of either gas, liquid or solid or in a combination thereof. Thus, wastes can be systematically divided into the categories: gas, liquid, solid, gas + solid, liquid + solid and gas + liquid.

The right hand column is a list of process numbers which identify processes required to dispose of the wastes listed in the corresponding row. For example, Process 6 is used to dispose of a gas + solid stream consisting of CO, $H_2O$ and solid carbon. Nine similar but separate processes to dispose of industrial wastes and one related process designed to burn a high nitrogen crude are described in the text. Five processes have been selected for discussion. These are listed in Table II.

## TABLE II
## SELECTED POLLUTION PROCESSES

| PROCESS | INDUSTRIAL | | POLLUTANT |
|---|---|---|---|
| | WASTE | FUEL | |
| 2.2 | PCB | | $Cl_2$, HCl |
| | VCM | | $Cl_2$, HCl |
| | PESTICIDES | | $Cl_2$, HCl |
| 3.0 | $NH_3$ | | $NO_X$ |
| | NITROSAMINE | | $NO_X$ |
| 5.2, 5.3 | NACL SOLUTION | | PARTICULATE |
| | POLYPROPYLENE/CATALYST | | PARTICULATE |
| 10.0 | | HIGH $N_2$ CRUDE | $NO_X$ |

Figure 1 contains four diagrams, one for each of the four configurations of a process to dispose of either a gaseous or liquid waste which produces a flue gas containing acceptable amounts of SOx and/or NOx. Configuration 1.1 is simply a Thermal Oxidizer, as shown previously in Figure A, which is supplied with waste, fuel and combustion air. Fuel is required when the waste's combustion energy is insufficient (endothermic) to produce a design operating temperature. An exothermic waste only requires fuel for pilot start-up. A highly exothermic waste requires a cooling medium such as excess air, steam or water, for temperature control.

Configuration 1.2 is a Thermal Oxidizer fitted with a heat recovery boiler. The boiler, with economizer, can recover approximately 85% of the heat energy supplied to the Thermal Oxidizer by the waste and fuel when the flue gas is cooled to 350°F.

Configuration 1.3 is a Thermal Oxidizer fitted with a gas-to gas heat exchanger. In the heat exchanger the flue gas is cooled and the waste gas heated. This method of heat recovery, when heating 60°F waste gas to within 400°F at an 1800°F operating temperature, can reduce a 40 MM BTU/hr, without preheat requirement, to approximately 8 MM BTU/hr. (Please refer to Figure 1A for an estimate of the fuel savings.)

Configuration 1.4 is a Thermal Oxidizer fitted with a gas-to-gas heat exchanger and a heat recovery boiler. The preheater heats the incoming combustion air and the boiler extracts the heat available in the flue gas from exchanger outlet temperature to 350°F. This configuration offers flexibility in the amount of steam produced versus fuel usage.

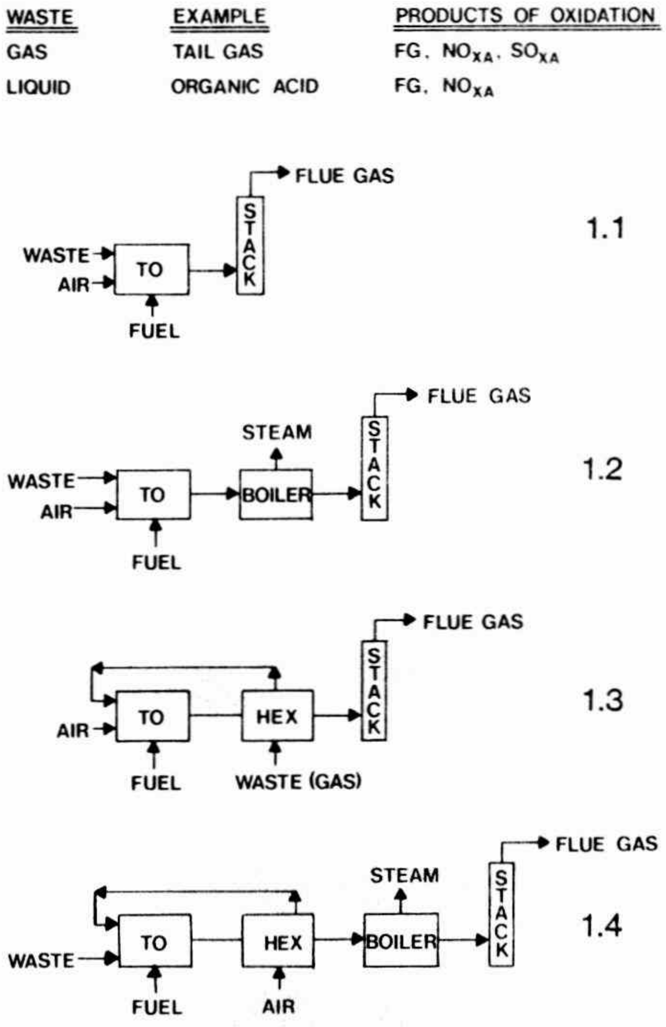


FIGURE 1 - WASTE PROCESS

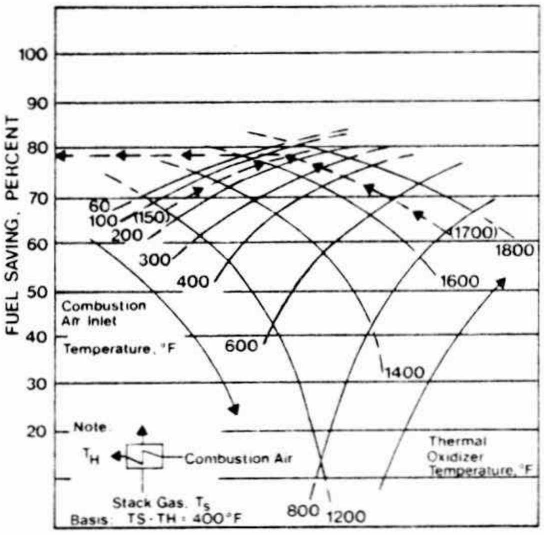


FIGURE 1A - FUEL SAVING

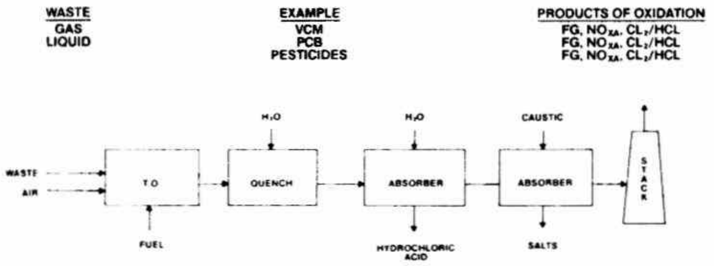


FIGURE 2.1 - WASTE PROCESS

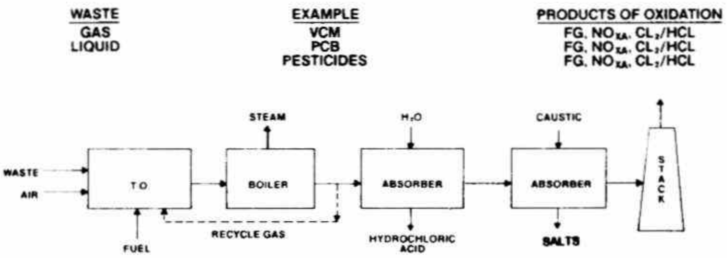
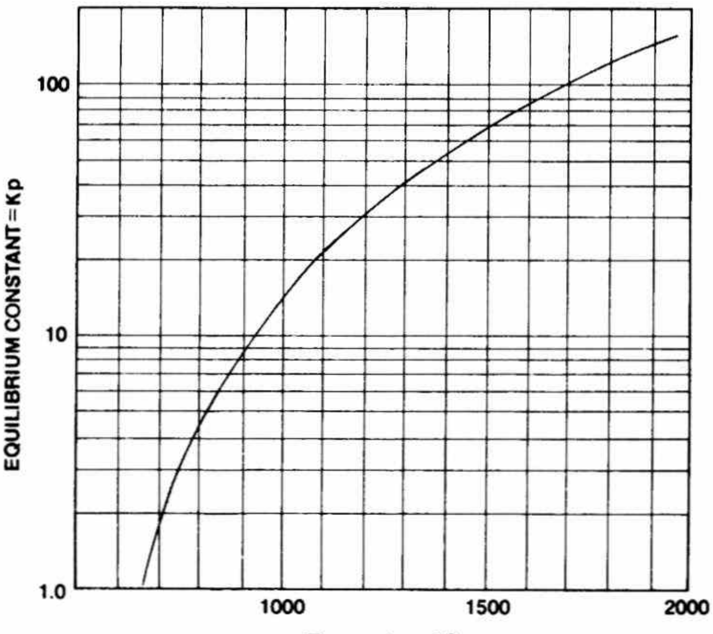


FIGURE 2.2 - WASTE PROCESS



$$Kp = \frac{(PHCL^2)(PO_2)^{1/2}}{(PH_2O)(PCL_2)}$$

**Rearranging gives:**

$$(PCL_2) = \frac{(PHCL)^2 (PO_2\ ^{1/2}}{Kp(PH_2O)}$$

**Figure 2A – Equilibrium Constant vs Temperature**

Figure 2 contains two block diagrams one for each of the two configurations of a process to dispose of either a gas or liquid waste, which produces flue gas containing excessive amounts of SOx or $Cl_2$/HCL.

Configuration 2.1 consists of a Thermal Oxidizer, a quench section which cools the flue gas to its saturation temperature by directly contacting it with water, two adiabatic absorbers which remove inorganic acids and chlorine and an unlined (no refractory) vent stack.

Water is used in the first absorber to remove a majority of the HCL from the flue gas. The remaining HCL and virtually all the entering $Cl_2$ leaves the absorber with the flue gas. A second absorber with caustic is used when either the $Cl_2$ or HCL in this stream exceed allowable levels. This occurs when excessive $Cl_2$ is formed in the Oxidizer (See Figure 2A for HCL/$Cl_2$ equilibrium) or when the first absorber is used to make strong HCL.

Configuration 2.2 consists of a Thermal Oxidizer, a heat recovery boiler which produces steam in cooling the flue gas to 350°F, two adiabatic absorbers, the first being fitted with a lower section of ceramic packing which cools the 350°F flue gas to saturation temperature prior to its entry into the acid absorption section. A second absorber for residual HCL and $Cl_2$ removal and an unlined vent stack.

Note that cool flue gas (recycle gas) is recycled to the Thermal Oxidizer for control of operating temperature when the waste is highly exothermic. This method of cooling is very important because it maximizes heat recovery. Other methods of cooling add mass to the system which increases the sensible heat lost from the system via an increased quantity of flue gas at the same exit temperature.

Figure 2B is a schematic of the system shown in Figure 2.2 which consists of horizontal T.O., fire tube boiler, quench column, acid absorber and caustic scrubber.

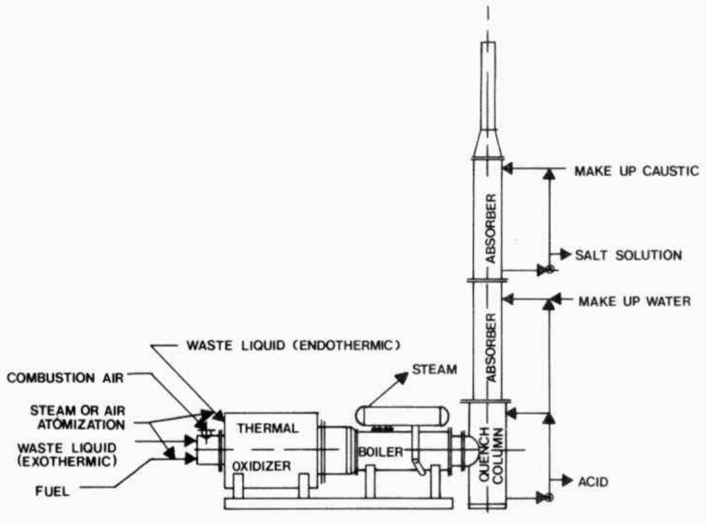
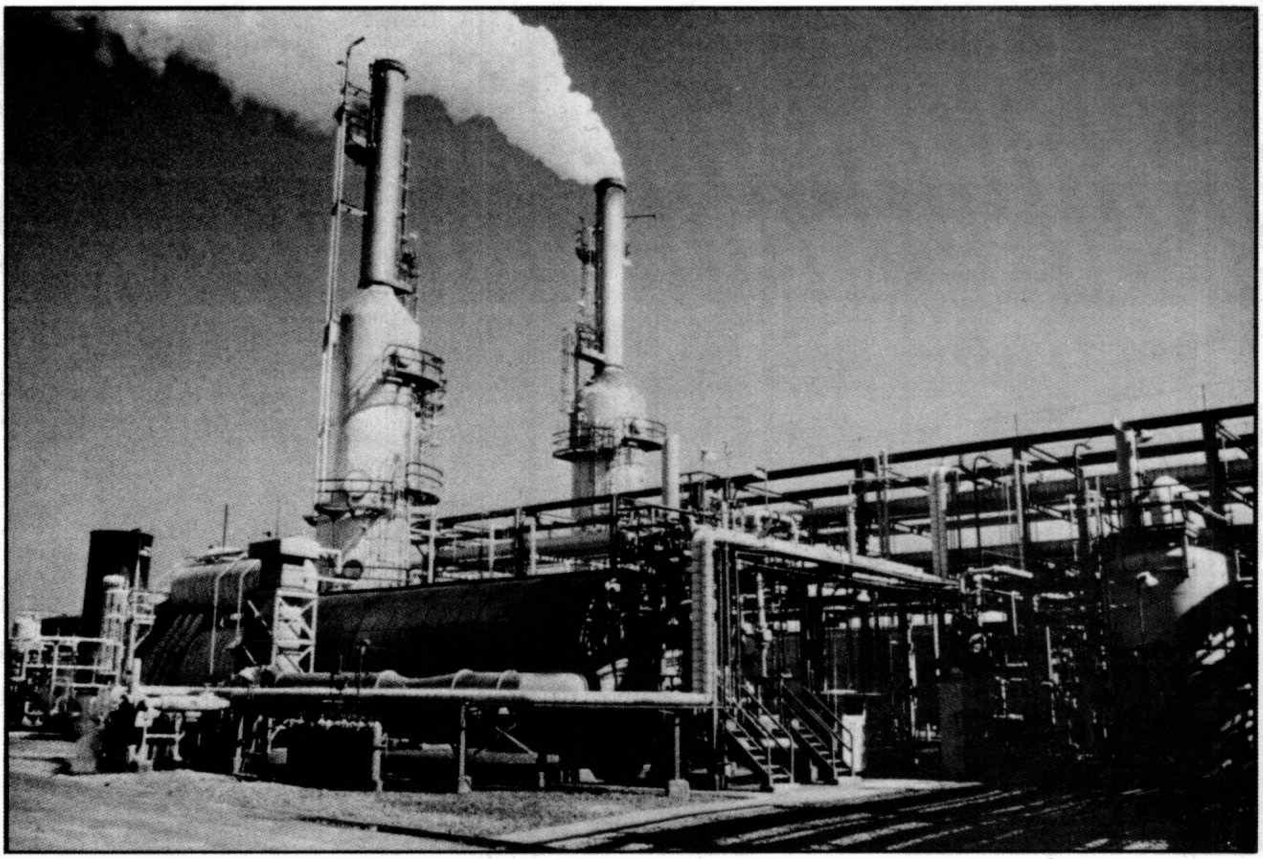


FIGURE 2B - CHLORINATED HYDROCARBON SYSEM



| WASTE CATEGORY | EXAMPLE | PRODUCTS OF OXIDATION |
|---|---|---|
| GAS | $NH_3$ | FG, $NO_x$ |
| LIQUID | NITROSAMINE | FG, $NO_x$ |

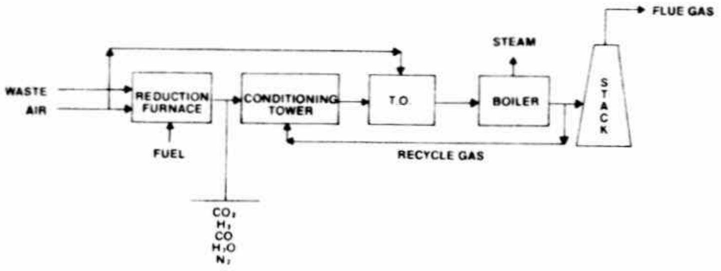


FIGURE 3 – WASTE PROCESS

Figure 3 is a block diagram of a two stage combustion process to dispose of either a gas or liquid that, when oxidized (one stage process), produces a flue gas containing excessive amounts of NOx. It consists of a reduction furnace in which a high temperature reducing (less than stoichiometric air) converts the fuel into $H_2$, $H_2O$, $CO_2$ and CO which converts the NOx present into $N_2$, quench section which cools the water gas to approximately 1400°F, by directly contacting it with cool recycle gas, a Thermal Oxidizer which converts the $H_2$ to $H_2O$ and CO to $CO_2$, heat recovery boiler which produces steam in cooling the flue gas to 350°F, and an unlined vent stack. Recycle gas cooling in lieu of air, steam or water is an integral part of this process to minimize NOx formation and maximize heat recovery.

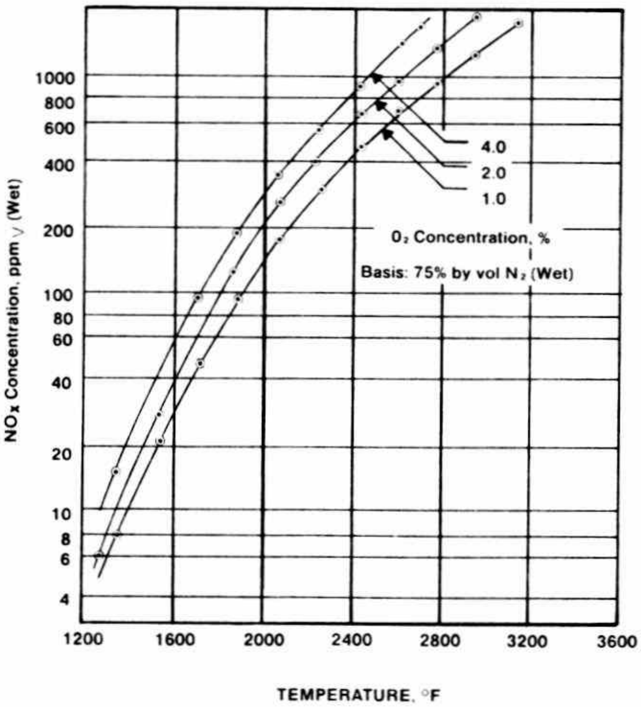


Figure 3A – Equilibrium $NO_x$ Concentration

The purpose of the cooling step is to lower the Thermal Oxidizer temperature. NOx production is related to the operating temperature as shown in Figure 3A which is a plot of NOx concentration versus temperature. For example, when 2% $O_2$ is present, an operating temperature of 1600°F has an equilibrium NOx value of 42 PPMv and at 2000°F has a NOx value of over 200 PPMv. Thus, it is desirable to operate at the lowest practical temperature. Another consideration is to oxidize the $H_2$ and CO present to meet regulations. The design becomes a trade off between the $H_2$ and CO allowables and NOx allowables.

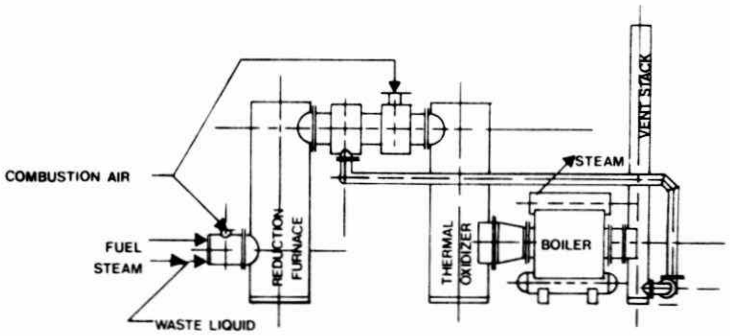


FIGURE 3B - $NO_x$IDIZER

Figure 3B is a schematic of a Noxidizer system.

Figure 4 is a block diagram of a process to dispose of either a gas or liquid that produces a flue gas containing $Cl_2$/HCL and excessive amounts of NOx. It consists of a reduction furnace in which a high temperature reducing environment converts NOx into $N_2$, the Cl into HCL and fuel into water gas, a quench station which cools the water gas to approximately 1400°F by directly contacting it with recycle gas, a Thermal Oxidizer which converts the $H_2$ to $H_2O$, CO to $CO_2$ and allows the HCL to come to equilibrium producing $Cl_2$/HCL, a heat recovery boiler which produces steam in cooling the flue gas to 350°F, an adiabatic absorber, fitted with a lower section of ceramic packing which cools the 350°F flue gas to saturation temperature prior to its entry into the acid absorption section which removes the inorganic acids, and an unlined vent stack. Recycle gas cooling is an integral part of this process to minimize NOx formation and maximize heat recovery.

Note that when the bound nitrogen compounds are contained in a feed stream separate from the chlorine containing stream, the chlorine stream can be admitted to the Thermal Oxidizer. This separation of streams would result in a smaller amount of products produced in the reduction furnace and thus a smaller reduction furnace which would be less costly.

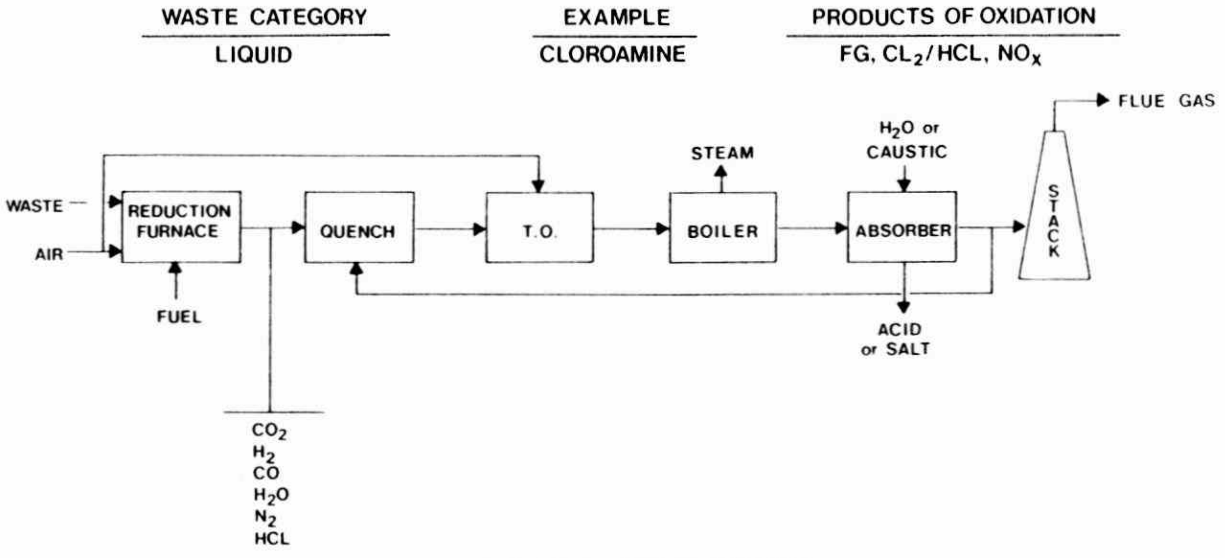


FIGURE 4 - WASTE PROCESS

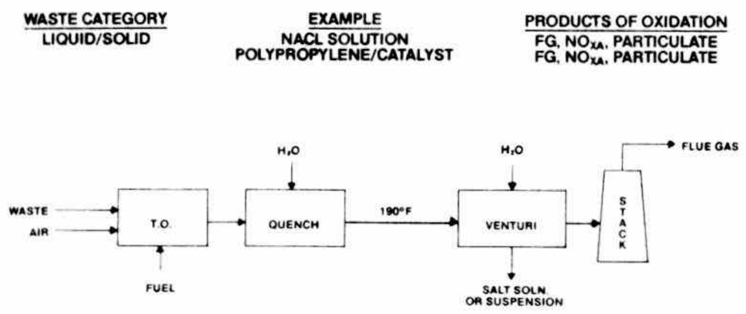


FIGURE 5.1 – WASTE PROCESS

Figure 5 is three block diagrams one for each of three configurations of a process to dispose of either a gaseous or liquid waste which produces flue gas containing excessive amounts of particulate matter.

Configuration 5.1 consists of a Thermal Oxidizer, a quench section which cools the flue gas to its saturation temperature by directly contacting it with water, a venturi scrubber which removes the particulate matter and a vent stack.

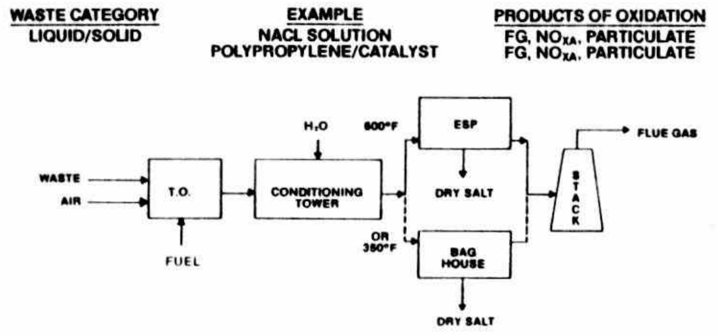


FIGURE 5.2 – WASTE PROCESS

Configuration 5.2 consists of a Thermal Oxidizer, a conditioning tower which cools the flue gas to either 600°F or 350°F depending upon the dry particulate removal system selected, by directly contacting it with water, with either an electrostatic precipitator or bag house for particulate removal, and an unlined vent stack.

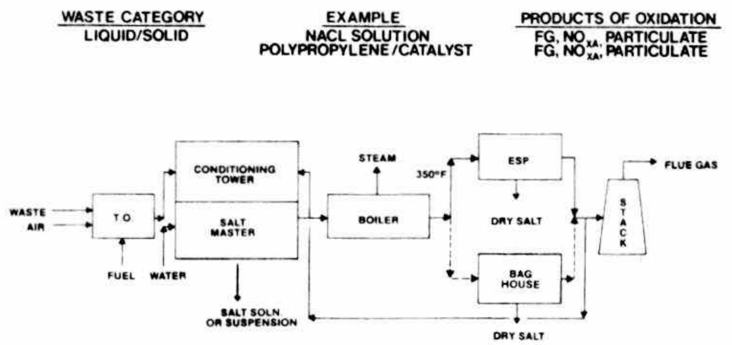


FIGURE 5.3 – WASTE PROCESS

Configuration 5.3 consists of a Thermal Oxidizer, a conditioning tower, fitted with a Salt Master,™ which lowers the flue gas to below salt fusion temperature by directly contacting it with recycle gas, a heat recovery boiler which produces steam in cooling the flue gas to 350°F, either an electrostatic precipitator or bag house for particulate removal, and an unlined vent stack. The Salt Master™ removes salt from the bottom of the conditioning tower before it can build up to the level sealing the inlet duct to the boiler. This would cause high system pressure drop causing system shutdown. Note, recycle gas is used for cooling to maximize heat recovery.

Figure 5A is a schematic of a down fired salt system.

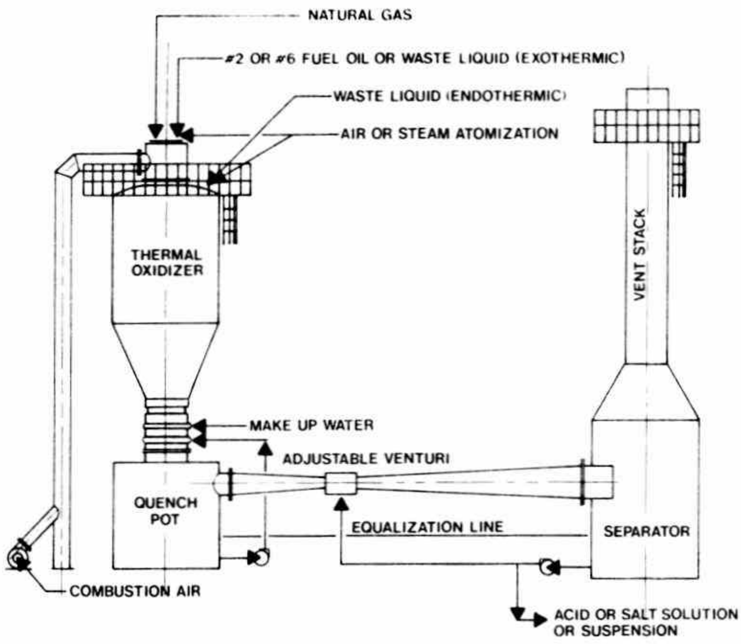


FIGURE 5A - DOWN FIRED SALT SYSTEM

Figure 5B is a schematic of a down fired salt system with heat recovery.

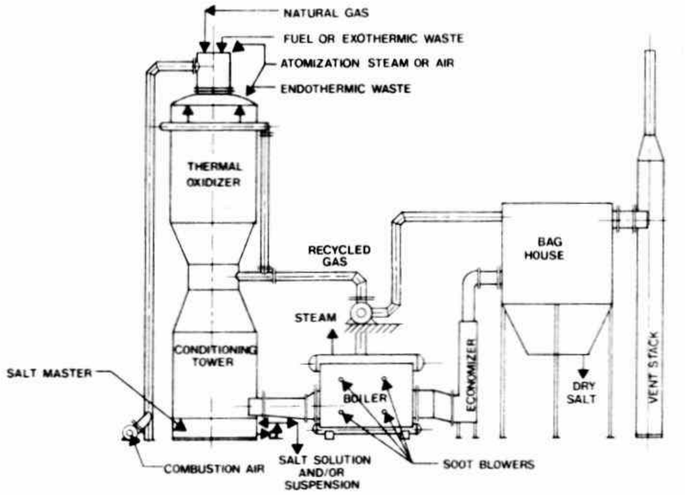


FIGURE 5B - DOWN FIRED SALT SYSTEM WITH HEAT RECOVERY

Figure 6 is three block diagrams, one for each of three configurations of a process to dispose of a waste containing combustible fine solids (less than $500\mu$) which produces flue gas containing acceptable amounts of SOx and/or NOx.

Configuration 6.1 consists of a cyclonic Thermal Oxidizer in which a high radial gas velocity causes the denser solid particles to be preferentially "slung" to the wall, thus markedly increasing their retention time, and a refractory lined stack.

Configuration 6.2 consists of a cyclonic Thermal Oxidizer fitted with a heat recovery boiler which produces steam in lowering the flue gas temperature to 350°F, and an unlined vent stack.

Configuration 6.3 consists of a cyclonic Thermal Oxidizer, fitted with a gas-to-gas heat exchanger, which heats the incoming combustion air, and a heat recovery boiler which recovers the heat available in the flue gas from the heat exchanger outlet temperature to 350°F and an unlined vent stack. This configuration offers flexibility in the amount of steam produced versus fuel usage.

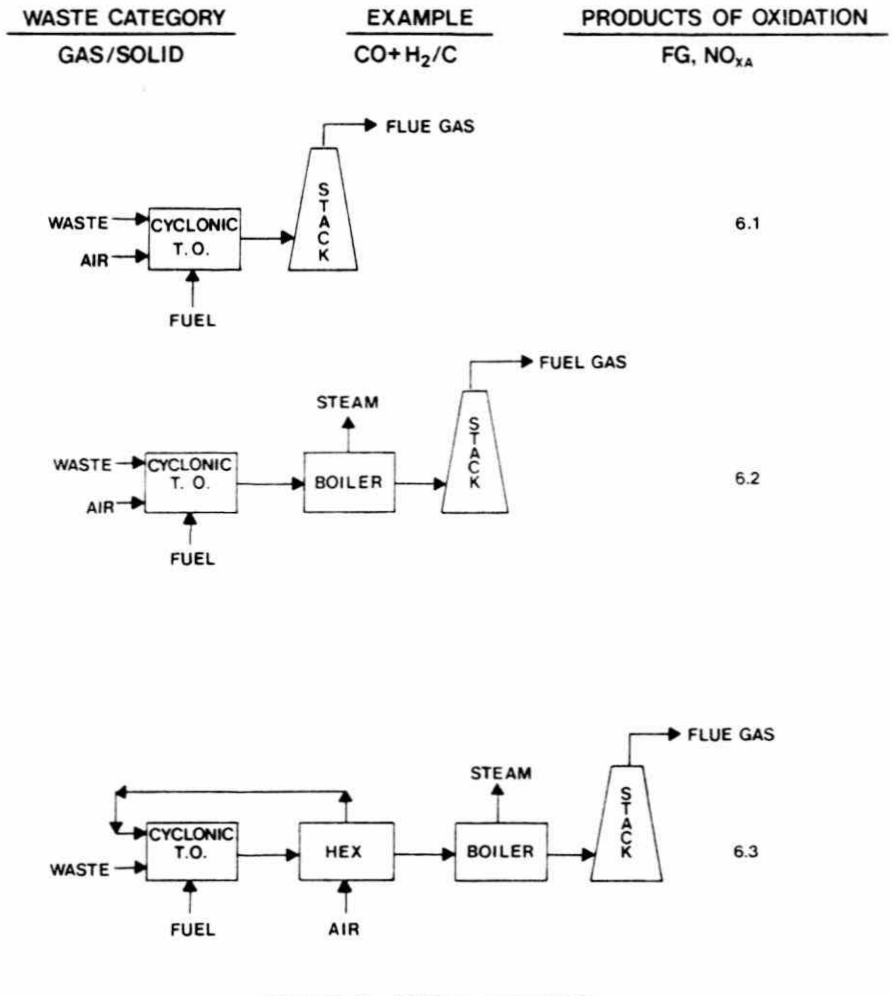


FIGURE 6 - WASTE PROCESS

Figure 7 consists of two block diagrams, one for each of two configurations of a process to dispose of a gaseous waste containing a combustible fine solid, (less than 500$\mu$) which produces flue gas containing acceptable amounts of SOx and/or NOx and excessive amounts of particulate.

Configuration 7.1 consists of a cyclonic Thermal Oxidizer and either a quench column, which by directly contacting the flue gas with water, cools it to its saturation temperature of approximately 190°F, and a venturi scrubber which removes the particulate matter, or a conditioning tower which by directly contacting the flue gas with recycle gas cools it to either 600 or 300°F, depending on the dry particulate removal system selected, and either an electrostatic precipitator or bag house for particulate removal, and an unlined vent stack.

Configuration 7.2 consists of a cyclonic Thermal Oxidizer, a hot cyclone for large particulate removal and/or conditioning tower which by directly contacting the flue gas with recycle gas cools it to below ash fusion temperature, a heat recovery boiler which produces steam in cooling the flue gas to 350°F, either an electrostatic precipitator or bag house for particulate removal, and an unlined vent stack. Recycle gas is used for cooling to maximize heat recovery.

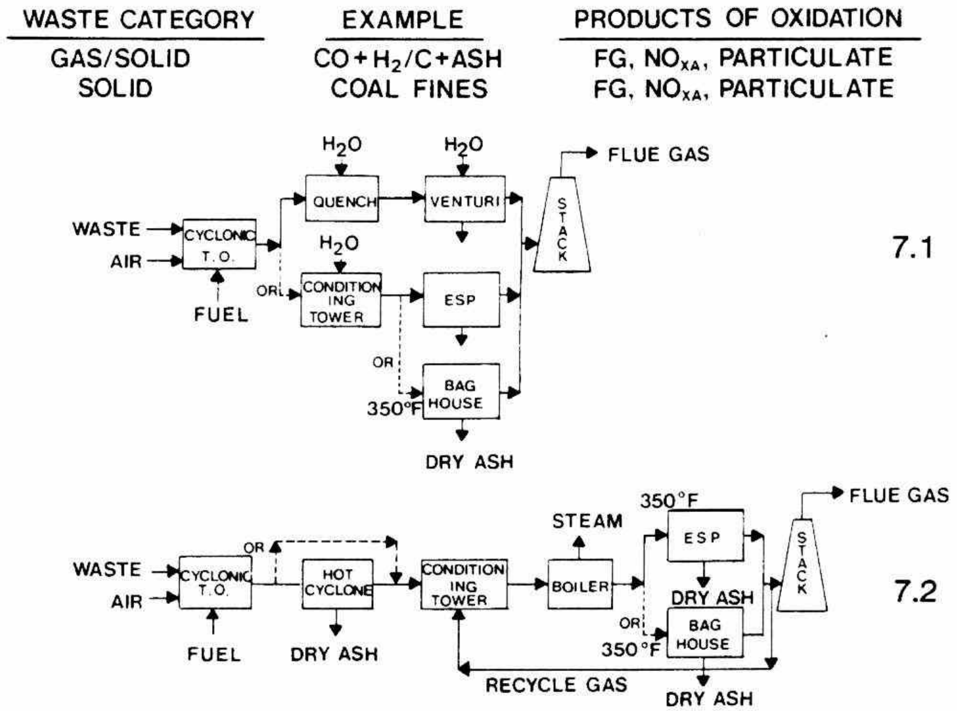


FIGURE 7 - WASTE PROCESS

| WASTE CATEGORY | EXAMPLE | PRODUCTS OF OXIDATION |
|---|---|---|
| LIQUID/SOLID | MELAMINE SLURRY | FG, $NO_x$ |
| SOLID | DNT CELLULOSE | FG, $NO_x$ |

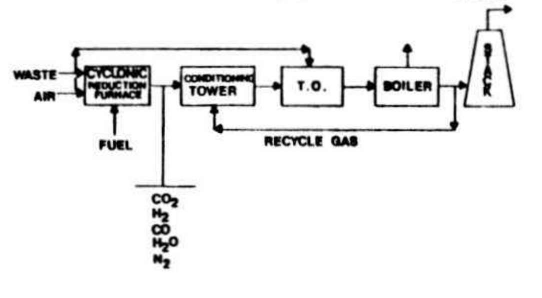


FIGURE 8 - WASTE PROCESS

Figure 8 is a block diagram of a process to dispose of a waste that contains combustible solids in the size range of 10 to 500$\mu$ that produces a flue gas containing excessive amounts of NOx. It consists of a cyclonic reduction furnace in which a high radial velocity, high temperature reducing (less than stoichiometric air) environment, converts the bound $N_2$ into $N_2$ and the fuel into water gas, a quench section which cools the water gas to approximately 1400°F, and a Thermal Oxidizer which converts the $H_2$ to $H_2O$ and CO to $CO_2$, a heat recovery boiler which produces steam in cooling the flue gas to 305°F and an unlined vent stack. Recycle gas cooling, not air, steam or water is an integral part of the process to minimize NOx formation and maximize heat recovery.

| WASTE CATEGORY | EXAMPLE | PRODUCTS OF OXIDATION |
|---|---|---|
| SOLID | ATACTIC POLYPROPYLENE/CATALYST | PARTICULATE |

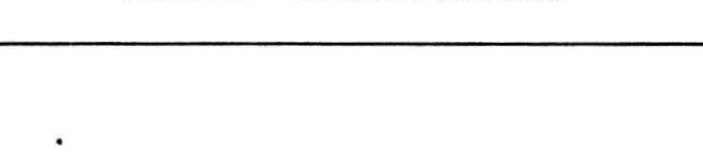


FIGURE9 - WASTE PROCESS

Figure 9 is a block diagram of a process to dispose of plastic chunks containing catalyst which produces flue gas containing excessive amounts of particulate. It consists of a reduction furnace which burns the waste in a pool on the furnace floor in a reducing environment producing a moderate BTU gas, a Thermal Oxidizer, a conditioning tower which, by directly contacting the flue gas with recycle gas, cools it to below salt fusion temperature, a heat recovery boiler which produces steam in cooling the flue gas to 350°F, either an electrostatic precipitator or bag house for particulate removal and an unlined vent stack. Recycle gas is used for cooling to maximize heat recovery.

Figure 10 is a block diagram of a two stage combustion process to burn a high nitrogen crude that, when oxidized (one stage), produces a flue gas containing excessive amounts of NOx.

This process is similar in concept to process three. It consists of a reduction boiler, substituting for process three's reduction furnace, in which a high temperature reducing (less than stoichiometric air) converts the high nitrogen crude into $H_2$, $H_2O$, $CO_2$, and CO which limits the formation of NOx and reduces any formed NOx into $N_2$, a smaller quench section than process three which cools the water gas to approximately 1400°F, by directly contacting it with cool recycle gas, a Thermal Oxidizer which converts the $H_2$ to $H_2O$ and CO to $CO_2$, convection boiler which produces steam in cooling the flue gas to 305°F, and an unlined vent stack. Recycle gas cooling in lieu of air, steam or water is an integral part of this process to minimize NOx formation and maximize heat recovery.

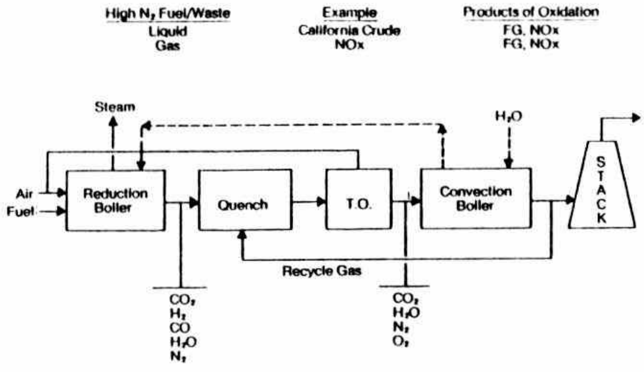


FIGURE 10 - WASTE PROCESS

Figure 10A is a schematic of the super Lo NOx boiler system.

Table III, entitled Lo NOx boiler data, lists data which indicate the capability of this system to control flue gas NOx.

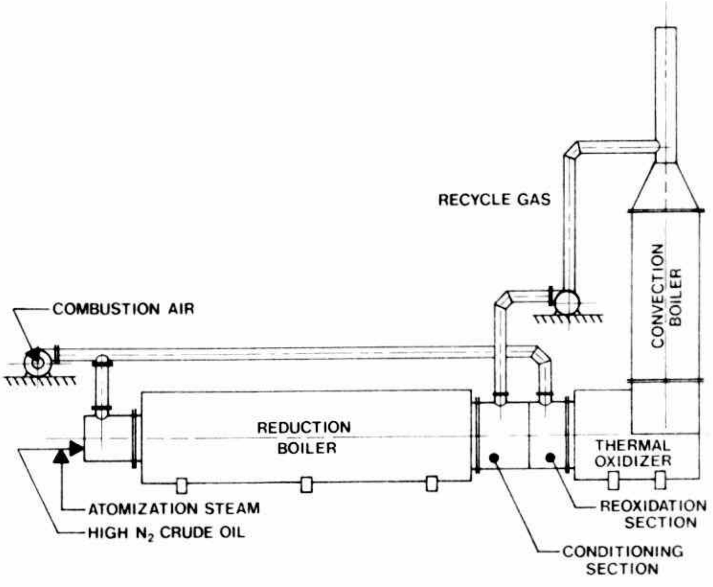


FIGURE 10A - SUPER LOW NOx BOILER

# TABLE III Lo NOx BOILER DATA

| No. | WASTE/FUEL | BURNER | T.O. TEMP., °F | FLUE GAS $O_2$ % Vol. Dry | $NO_x$, PPMV, Dry | | |
|---|---|---|---|---|---|---|---|
| | | | | | EPA | SGA | TEA |
| **NOXIDIZER** | | | | | | | |
| 1 | Anhydrous $NH_3$ | HI-3 | 1508 | 2.8 | 24 | 45 | — |
| 2 | Anhydrous $NH_3$ | HI-3 | 1550 | 1.2 | 59 | 106 | — |
| 3 | Anhydrous $NH_3$ | HI-3 | 1504 | 2.2 | 27 | 120 | — |
| 4 | Anhydrous $NH_3$ | HI-3 | 1635 | 2.2 | 12.3 | 41 | — |
| 5 | Anhydrous $NH_3$ | HI-3 | 1614 | 1.3 | 31 | 46 | — |
| 1 | Acrylonitrile +Amide+Amine | HI-3 | 1902 | 3.4 | 43 | 150 | — |
| 1 | #6 Oil | HI-3 | 1583 | 2.4 | — | 80 | — |
| 2 | #6 Oil | HI-3 | 1564 | 2.0 | — | 95 | — |
| 1 | California Crude Oil | HI-7 Modified | 1734 | 2.2 | 76.1 | 105 | — |
| 2 | California Crude Oil | HI-7 Modified | 1510 | 3.67 | — | 105 | — |
| 3 | California Crude Oil | HI-7 Modified | 1852 | — | — | 140 | — |
| 4 | California Crude Oil | HI-7 Modified | 1641 | 2.3 | — | 93 | — |
| **LO-$NO_x$ Boiler** | | | | | | | |
| 1 | Natural Gas | HI-3 | 1565 | 2.4 | — | 30 | — |
| 2 | Natural Gas | HI-7 | 1598 | 3.1 | 42.8 | — | — |
| 3 | Natural Gas | HI-7 | 1525 | 2.0 | — | 25 | — |
| 4 | Natural Gas | HI-7 Modified | 1519 | 4.8 | — | 27 | — |
| 5 | Natural Gas | HI-7 Modified | 1551 | 4.3 | — | 30 | — |
| 6 | Natural Gas | HI-7 Modified | 1570 | 4.8 | — | 25 | — |
| 1 | #2 Oil | HI-7 | 1717 | 4.0 | — | 65 | — |
| 2 | #2 Oil | HI-7 | 1591 | 1.3 | — | 55 | — |
| 1 | #6 Oil | HI-7 Modified | 1599 | 4.2 | — | 105 | — |
| 2 | #6 Oil | HI-3 | 1719 | 3.6 | — | 98 | — |
| 1 | California Crude Oil | HI-7 Modified | 1880 | 7.4 | — | 300 | — |
| 2 | California Crude Oil | HI-7 Modified | 1953 | 2.2 | — | 470 | — |
| 3 | California Crude Oil | HI-7 Modified | 1616 | 4.0 | — | 120 | — |
| 4 | California Crude Oil | HI-7 Modified | 1610 | 3.0 | — | 122 | — |
| 5 | California Crude Oil | HI-7 Modified | 1601 | 2.6 | 126.5 | 135 | — |
| 6 | California Crude Oil | HI-7 Modified | 1757 | 2.8 | — | 115 | — |
| 7 | California Crude ($C_2$) | HI-3 #6 | 1875 | 2.4 | 46 | — | 73 |
| 8 | California Crude ($C_2$) | HI-3 #6 | 1868 | 2.6 | 48 | — | 78 |
| **3** | **California Crude Oil** | **Flue Gas No$_x$ Concentration corrected to 3% $O_2$** | | | | **—** | **127** |
| **4** | **California Crude Oil** | **Flue Gas No$_x$ Concentration corrected to 3% $O_2$** | | | | **—** | **122** |
| **5** | **California Crude Oil** | **Flue Gas No$_x$ Concentration corrected to 3% $O_2$** | | | | **123.7** | **132** |
| **6** | **California Crude Oil** | **Flue Gas No$_x$ Concentration corrected to 3% $O_2$** | | | | **—** | **114** |
| **7** | **California Crude ($C_2$)** | **Flue Gas No$_x$ Concentration corrected to 3% $O_2$** | | | **48.5** | **—** | **71** |
| **8** | **California Crude ($C_2$)** | **Flue Gas No$_x$ Concentration corrected to 3% $O_2$** | | | **50.5** | **—** | **76** |

EPA – Environmental Protection Agency
SGA – Source Gas Analyzer
TEA – Thermal Electron Corporation

# Monitoring Volatile Industrial Wastes - The TAGA Approach

by

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## Abstract

The TAGA (Trace Atmospheric Gas Analyzer) system provides Environment Ontario with one of the most advanced and sophisticated means available to monitor volatile industrial wastes. Its sensitivity, speed, and versatility allow the system to be adapted to many of the Ministry's environmental concerns.

The TAGA 3000 system is an atmospheric pressure chemical ionization (APCI) mass spectrometer which is capable of detecting and quantifying a broad range of organic and inorganic contaminants. It is part of a completely self-contained mobile laboratory which has been outfitted with a dedicated computer system, meteorological instrumentation, and communication systems. The unit is powered by two six-kilowatt generators located in the rear of the vehicle.

Direct air sampling coupled with APCI affords near instantaneous response to ultra-trace levels (sub-ppb) of volatile pollutants. This versatile system can be operated in either one of two modes: (a) the mass scan (MS) mode to produce a 'fingerprint' of

the components in the sampled air or, (b) the selected ion monitoring (SIM) mode for compiling real-time measurements of up to eight pollutants simultaneously. This latter feature has proven to be most valuable in responding to emergency chemical spill situations such as train derailments when ambient air concentration information was crucial.

During the past two years Environment Ontario's mobile TAGA 3000 system has been instrumental in providing vital emissions data for a variety of industrial-related sources including: chemical manufacturing plants, landfill sites and chemical spills. This paper briefly describes the Ministry's mobile TAGA system as it has been applied to addressing these particular environmental concerns. Some examples of actual field work recently conducted by the Air Resources Branch will be presented.

## Introduction

For the past few years, scientists at the Air Resources Branch of Environment Ontario have been applying the mobile Trace Atmospheric Gas Analyzer, model 3000 (TAGA) to the challenging task of monitoring volatile compounds in the ambient air. The TAGA unit is also key ingredient of the Ministry's emergency response contingency plans.

Essentially, the TAGA system is an atmospheric pressure chemical ionization (APCI) quadrupole mass spectrometer mounted in a mobile van. Its unique features of hypersensitivity and direct air sampling permit the rapid analysis of complex matrixes without prior pre-concentration techniques. A large range of organic and inorganic compounds can be measured in the real-time while either mobile (plume tracking) or stationary.

The TAGA unit is usually assigned to those environmental concerns where there exists a need for either real-time mobile monitoring of a specific pollutant (or pollutants) or when the identities of the pollutants being emitted are unknown. The logistics of the more traditional techniques (i.e. adsorbent trapping followed by GC analysis) renders their application inappropriate in these instances.

In this paper the TAGA approach to monitoring industrial wastes will be discussed. Specific examples will be given to exemplify the scope of applications to the environmental field ranging from fingerprinting the emissions from landfill sites to monitoring toxic chemicals released from derailed tank cars.

## The Van

A twenty-six foot GMC "Transmode" recreational vehicle was chosen to house the TAGA 3000 because of its unique feature of self-levelling air bag suspension. A smooth vibration free ride is essential for the mobile operation of the on-board computer system. Other fundamental equipment installed includes: a ten meter telescopic tower which supports the meteorological instrumentation;

communication systems (to relay vital air quality data to a command centre); gas supply system; refrigerator for chemical storage; various work spaces and storage facilities. An automatic fire repression system was recently added to protect the van's valuable contents.

The unit is powered by two six-kilowatt air-cooled "Onan" generators; one supplies power to the TAGA and computer circuits while the other supports the auxillary circuit which feeds power to the heaters, air conditioners, cooling fans, receptables, and lights. Since either circuit can be activated by either generator the TAGA can remain functional in crucial monitoring situations even if one generator should fail.

## The Instrument

The TAGA technology is based on the principles of atmospheric pressure chemical ionization (APCI) coupled with quadrupole mass spectrometry (MS). Ambient air is sampled directly and continuously into the ion source at a typical flow rate of 1.5 L/S. The high flow rate through the large bore (22 mm) all glass and "Teflon" sampling line minimizes the 'memory' effects due to wall adsorption.

Contaminants carried by the flowing ambient air, become ionized as they pass through a point-to-plane corona discharge. These ions are then directed electrostatically through a 100 micron orifice into a vacuum region for mass spectral analysis and detection. The atmospheric-to-vacuum interface assembly only permits ions and ultra pure nitrogen to pass into the vacuum region, repelling the particulate matter and the non-ionized contaminants. This is accomplished through the utilization of a unique counter-flowing curtain gas.

The vacuum system consists of a two stage, closed-loop, helium cryogenic refrigerator coupled to a baffled cryo-array. Apparently this system can achieve pumping speeds of 20,000 L/S at the operating pressure of $10^{-6}$ torr. Cryogenic systems are noted for being extremely clean and requiring little maintenance. However after approximately 40 hours of use the vacuum system has to be recycled; that is, the solidified gases (mostly nitrogen) are allowed to warm-up and be exhausted from the vacuum chamber.

The quadrupole mass filter has a continuous mass scan range of 2 to 560 atomic mass units. Upon exiting from the mass filter, the ions are detected by an electron multipler (Channeltron) and finally a digitilized signal is transferred to the computer and CRT unit for visual display. See Figure 1 for an overview of the instrument.

Complete control of the TAGA is facilitated by the on-board dedicated computer system. The TAGA operator interacts with the system in the real-time through a CRT graphics terminal. Data are permanently recorded by a double-density, dual floppy disc system and can be instantly printed by a hard-copy unit.

## Atmospheric Pressure Chemical Ionization

Basically APCI is a chemical means of ionizing the trace compounds in air such that the TAGA can 'see' them. The main advantage of chemical ionization is that it is a 'soft' ionization process, and the ionized species remains intact thus the mass or molecular weight is readily obtained. This is in contrast to the 'hard' ionization process of electron impact ionization which imparts higher energies to the ions causing them to fragment. For direct analysis of complex mixtures this fragmentation effect is unfavourable since the molecular weight information may be lost, not to mention a reduction in sensitivity.

In addition, APCI allows the TAGA operator to perform 'in-situ' separation of the pollutants into their chemical classes through the use of specific chemical ionization reagents. For example, ammonia vapour can be added to the sample gas stream to instantaneously separate amines from the bulk sample. This is achieved through selective chemical ionization governed by the ammonia molecules. The net effect of chemical ionization is a much simplified spectra for interpretive purposes.

In general, the instrument is sensitive to those chemicals which contain a heteroatom such as O, N, P, S, halogen, metal, etc. Alkanes, alkenes and low molecular weight halocarbons are not readily and unambiguously detected with the TAGA under APCI conditions. However, preliminary research indicates that the new low pressure ion source may aleviate this shortcoming by expanding the range of detectability to include some of these chemical classes.

Trace species can be detected in the ppt to ppm concentration range. The actual sensitivity or quantitative response for a particular chemical is greatly dependent on the composition of the matrix. Therefore, on-site calibrations are usually performed to obtain accurate quantitative data.

## Field Applications

The unique features of the mobile TAGA system permit it to be applied to an assortment of the Ministry's monitoring requirements. In general, the applications of the TAGA unit include: isolation and/or identification of sources; fingerprint analyses of complex air pollution; confirming the effectiveness of industrial abatement devices; mapping of ground-level concentrations (GLC's); odour identification and emergency reponse to hazardous spills. In the discussion that follows a number of actual field studies are cited which best exemplify the power of the technique and the kinds of information that the mobile TAGA unit can generate.

As the uses of the TAGA unit expanded, a certain survey strategy evolved for sampling, detecting and quantifying a large variety of volatile pollutants at trace levels. The systematic approach usually adopted is a two phased process. Firstly, a qualitative fingerprint of the emissions is derived from scanning over a wide mass range; secondly quantitation of a select number of target compounds is procurred through selected multiple ion monitoring. The extent to which the Survey Strategy Plan (SSP) is executed depends on the potential complexity of the environmental matrix and the specific information sought.

## Case One: An Chemical Manufacturing Plant

In response to reports by local inhabitants of noxious 'fish-like' odours, the TAGA unit was dispatched to investigate a chemical manufacturing plant. Sampling in the vicinity of the chemical plant was conducted in the spring with excellent results. The skies were clear, the wind direction from the northwest; the wind speed was between 5 and 10 km/hr; and ambient air temperature was 25°C.

Just downwind of the plant, approximately 20 meters to the south of the facility, a public road, running east-west, was found ideal for monitoring the emissions. For this study, the TAGA was utilized in the real-time, multiple ion scanning mode. The characteristic ions of three pre-selected target compounds, namely monomethyl amine (MMA), dimethyl amine (DMA) and trimethyl amine (TMA), were monitored as a function of distance (see Figure 2). The instantaneous responses were recorded every 2 seconds for a period of 10 minutes while the van was driven along the public road at 20 km/hr. As clearly seen the concentration of the three amines increased substantially, 10 to 100 fold, as the TAGA passed close by this facility. The boundaries of plume and the position of maximum GLC's were readily located during this single transverse.

The data leave little doubt of the identity and source of the odourous pollutants. In just a few hours the TAGA unit produced the emissions information required for the environmental officers to engage in discussions with the plant personnel regarding the appropriate industrial abatement measures.

## Case Two: A Chemical Manufacturing Plant

The subject of this survey was a chemical plant which supplies chemicals for the rubber manufacturing industry. The plant is located on the edge of a small town in central Ontario. Presented here are only samples of the most recent TAGA results which show the fingerprinting capabilities of APCI-mass spectrometry.

For several days during late May, 1981, Phase 1 of the Survey Strategy Plan was implemented in order to assess the extent of the emissions from the industry. Essentially the procedure involved collecting mass scans at various positions upwind and downwind of the plant. The downwind positions were determined by locating the maximum GLC for a chemical unique to the plant via plume tracking techniques. Then mass scans of the air were taken for a variety of chemical ionization reagents. Background correction was accomplished by simply subtracting the upwind signal from those recorded downwind. (This is actually done by the on-board computer system.) A sample of the resultant fingerprinting information is presented in Figure 3. The tentative identification of the mass spectra were based on the chemical ionization data, and knowledge of the company's chemical inventory. In all, some 20 chemicals were observed in the abundance range of ppt to low ppb.

The next phase of the study is scheduled to proceed later this year and will entail quantitation of five target compounds considered by the Ministry's medical consultant to be of greatest concern.

## Case Three: An Industrial Waste Landfill Site

In the late summer months, the TAGA was used to analyze the gases emanating from a former industrial waste landfill site. In view of the fact that the inventory of chemicals dumped at the site is unknown, the situation presented the most challenging analytical task yet to be addressed by the TAGA unit.

Sampling of a number of man-made vents was performed by extending a glass line from the TAGA ion source directly into the vents. The usual wide range mass scans were recorded for several CI reagents. These were compared to readings taken at an upwind position.

Although the results are preliminary, there is some evidence that a wide spectrum of chemicals are being emitted from the landfill site. In fact, some two to three hundred chemicals have been tentatively identified. Order-of-magnitude estimates of the concentrations indicate low parts per billion levels. On-site quantitation of some chemical class representatives are expected in the near future.

## Case Four: Emergengy Response

Perhaps the value of a mobile TAGA system was best demonstrated when emergency monitoring was required. Over the past three years the TAGA unit has responded to two environmental emergencies both of which involved train derailments; namely, the well-publicized Mississauga incident and the very recent Medonte Township derailment.

On November 10, 1979 twenty-four railway cars derailed at the Mavis Road crossing in the city of Mississauga, Ontario. A tank car containing 90 tons of liquid chlorine began to leak, and propane from ruptured tank cars burned for several days. Emergency contingency plans were implemented and more than 200,000 residents were evacuated from the surrounding area.

At 8:00 am on November 11, TAGA units were summoned to track the chlorine plume and measure the maximum concentration therein. Typical concentration profiles as generated by traversing the plume with the TAGA unit are shown in Figure 4. This information was most valuable in assisting the authorities in establishing the areas of evacuation and ensuring the safety of the emergency personnel.

On Sunday, February 28, 1982, thirty-nine railway cars derailed in the rural area of Medonte Township near Orillia, Ontario. Both the MAM (Mobile Air Monitoring) and TAGA units of the Air Resources Branch were commissioned to the crash site because a tanker of anhydrous hydrogen fluoride (HF) had not been located in the entangled wreckage, and its status was unknown. The TAGA was the only instrument available that could instantaneously detect HF. (Just months previous to the accident, Ministry TAGA scientists had developed the methodology to unambiguously detect and quantify trace amounts of HF in ambient air.)

Within four hours of the request, a TAGA unit was at the scene providing vital air quality data to the authorities. The MAM unit was responsible for obtaining the local meteorological parameters which was essential for the dispersion models and positioning of the TAGA unit.

The air downwind of the wreck was screened for HF, chlorinated compounds, and cyanide (possible products from burning plastics) while the work crews re-positioned the tank car and pumped its toxic contents to a second car. Fortunately the entire clean-up programme proceeded without an incident and at no time was HF detected above the few hundred ppt detection limit. Due to the high toxic nature of HF and the high risk potential for the emergency personnel the TAGA was calibrated and tested daily with a certified HF gas mixture especially prepared for this situation.

In conclusion, the TAGA unit has proven to be a very versatile analytical tool for monitoring a variety of volatile industrial wastes. Undoubtedly the uses of the TAGA will expand as the data base grows through the field survey programmes, as well as our continuing research and development efforts.

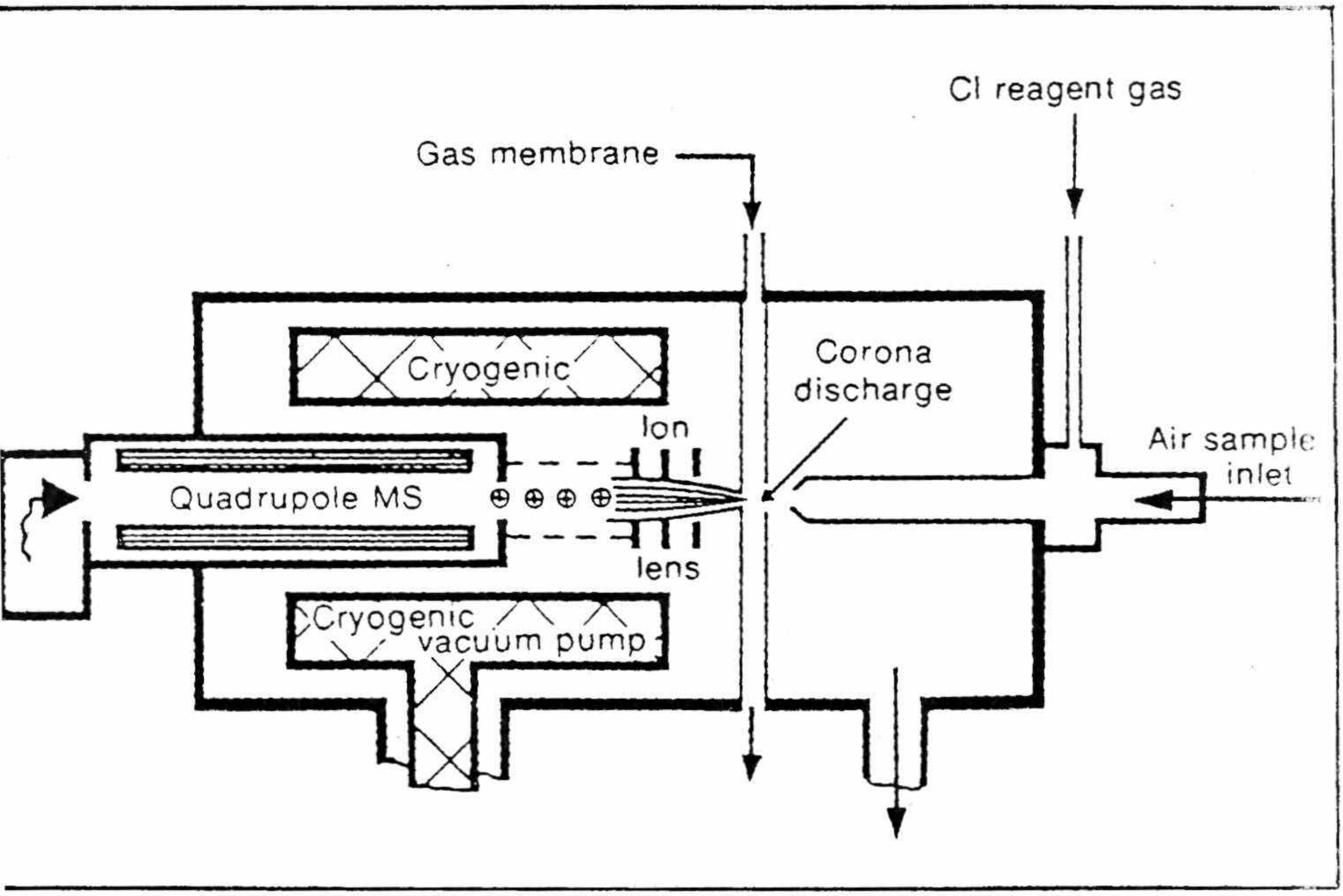

FIGURE 1. SCHEMATIC OF THE TAGA 3000 SYSTEM.

CHEMICALS PLANT

SURVEY #1. REAL-TIME MULTIPLE ION SCAN(MOBILE)

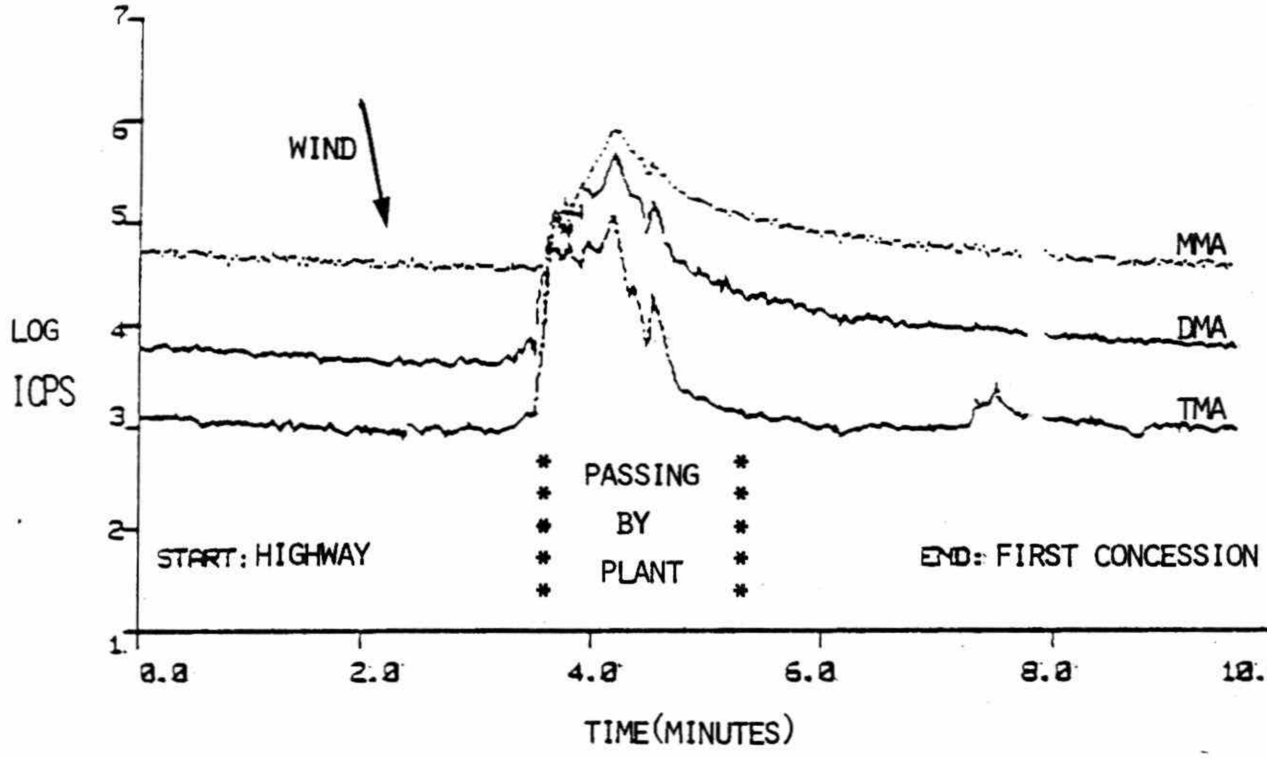

FIGURE 2. PLUME TRACKING OF MMA, DMA AND TMA DOWNWIND OF CHEMICAL PLANT.

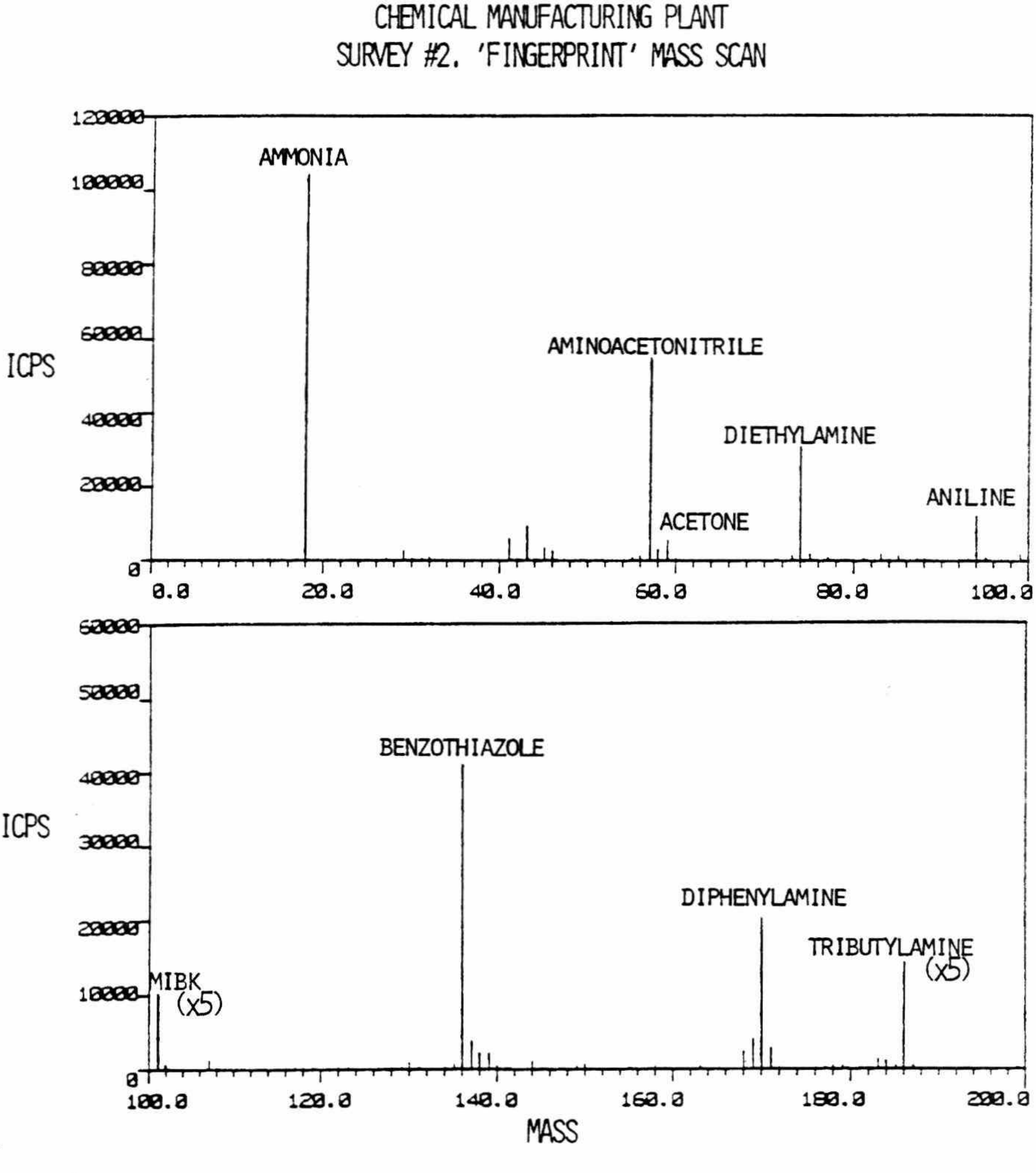

FIGURE 3. FINGERPRINT MASS SCAN OF CHEMICAL MANUFACTURING PLANT.

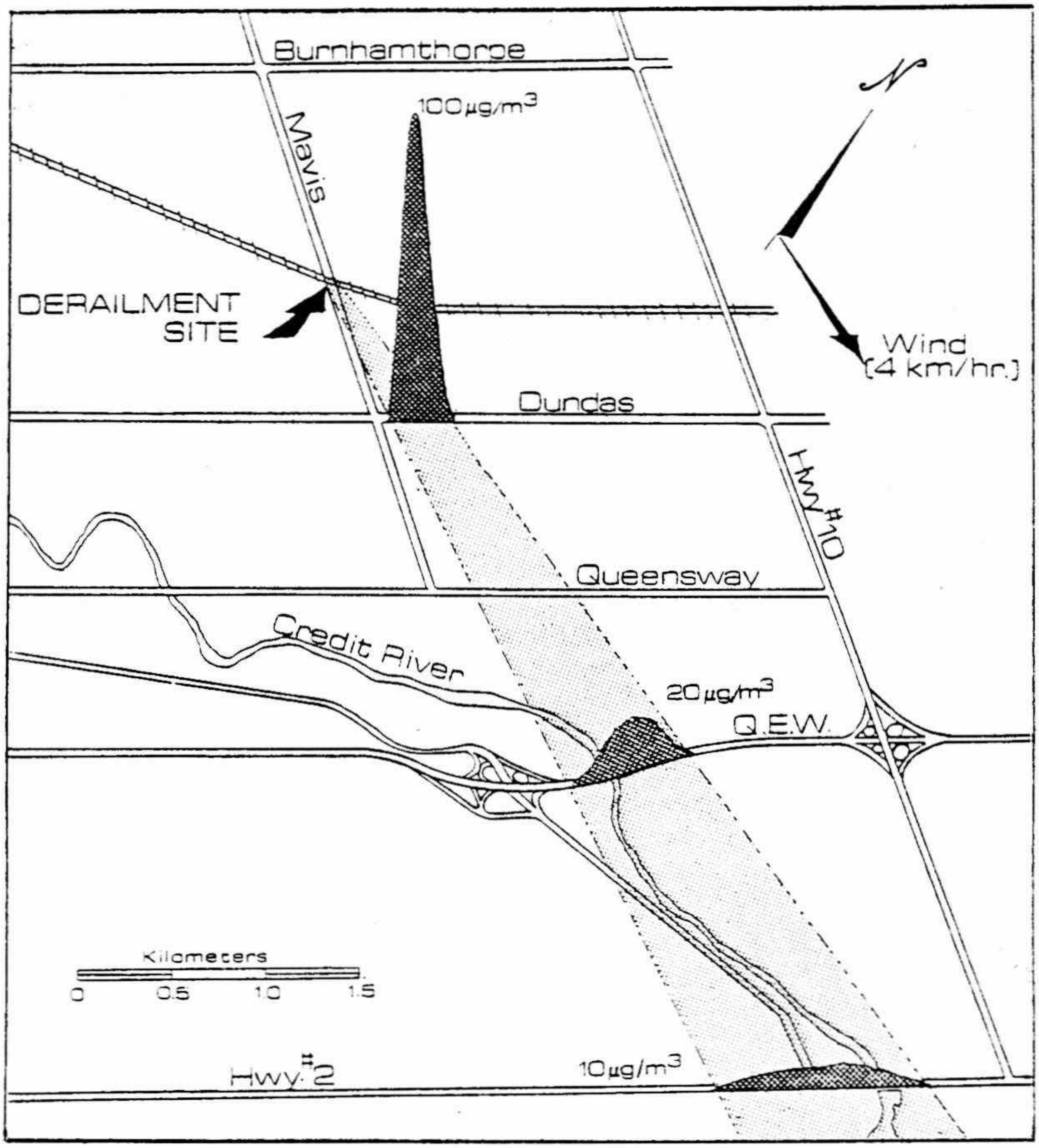

FIGURE 4. THREE PLUME CROSS-SECTIONS TAKEN BETWEEN 5:30 AND 6:30 ON NOVEMBER 14, 1979.

# TORONTO AIR POLLUTION EPISODE

November 13-15, 1981

by

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# ABSTRACT

A classical air pollution episode occurred on November 13 to 15, 1981. A high pressure system remained above and around Lake Ontario throughout the episode. Stagnant wind conditions and strong temperature inversions resulted in little vertical mixing and poor dispersion of air pollutants. The Air Pollution Index (API) in downtown Toronto reached a three year high of 43.

This episode was unique in that the major industrial sources were not operating throughout the period. Excessive levels of suspended particulate matter, carbon monoxide, lead, and oxides of nitrogen were monitored and a strong diurnal pattern was observed. Sulphur dioxide concentrations remained low throughout the episode. High concentrations of various pollutants were also detected in other urban areas around Lake Ontario. It was concluded that the elevated pollutant levels resulted more from local sources than long range transport. Automobile emissions were the major contributors.

# 1. INTRODUCTION

On Friday, November 13, 1981, the Air Pollution Index in Toronto as measured at Station 31104 (26 Breadalbane Street) rose rapidly from 22 (1400 to 1600 EST) to the Air Advisory Level of 32 at 2200 EST. It exceeded 32 on Saturday, November 14, 1981 at 0000 EST and reached a maximum of 43 between 0500 and 1300 EST.

The Index remained above the Air Advisory Level for 30 hours but did not reach its First Air Pollution Alert of 50. On Sunday, November 15, 1981, the Index dropped below 32 at 0800 EST and further to below 20 at 1900 EST.

The Air Advisory Level of 32 was exceeded on two other occasions in 1981. The first occurred on October 15, 1981 between 2000 and 2200 EST. A maximum index of 35 was recorded. The other episode lasted for approximately 13 hours with a maximum index of 37. It occurred between 1600 EST on November 5, 1981 and 0400 EST on November 6, 1981.

In 1981, the Toronto Index has never reached the First Air Pollution Alert of 50.

# 2. BACKGROUND

## 2.1 Air Pollution Index (API)

The Ontario Air Pollution Index value is related to the hourly sulphur dioxide concentration and soiling index of suspended particulate matter, as given by the expression:

$$API = 0.2\ [126.0(SO_2) + 30.5\ (COH)]^{1.35}$$

The design of the above equation and information on the Air Pollution Alert System can be referred to the FACTS publication in Appendix A.

## 2.2 Meteorological Aspects of Air Pollution

Examination of the meteorological data indicated that the November episode resulted from stagnant wind conditions and strong temperature inversion which prevented dispersal of suspended particulate matter.

When the lapse rate (decrease of temperature with height) is less than the abiabatic (atmospheres with lape rates of about 10°C $kilometre^{-1}$), the air is said to be stable because vertical motion is damped. An inversion occurs when the temperature actually increases with height, resulting in strong stability and very little vertical mixing.

# 3.0 AIR QUALITY ASSESSMENT

## 3.1 Air Pollution Index - Sulphur Dioxide and Soiling Index

The Toronto air pollution index rose to the Air Advisory Level of 32 in the early morning of November 13, 1981 and continued to exceed the desirable criteria for approximately 30 hours. Similar trends were observed at most major air monitoring stations along Lake Ontario.

Figure 1 illustrates the API recorded at Hamilton, Oakville, downtown Toronto, Toronto east and Oshawa. All displayed a similar peak on November 14, 1981 with the exception of the Oakville station (Bronte Road/Woburn Crescent), whose index never surpassed 20.

Sulphur dioxide ($SO_2$) levels were low throughout the episode (Figure 2) and did not exceed both the hourly and 24-hour average criteria (0.25 ppm and 0.10 ppm, respectively).

However, the soiling index at Station 31104 (downtown Toronto) exceeded the 24-hour desirable ambient air quality criterion of 1.0 COH/1,000 ft. The 24-hour average were 1.3 and 1.4 COH/1,000 ft. on November 13 and 14, 1981, respectively.

High values of soiling index were also detected at other continuous monitoring stations. Very similar trends were recorded as illustrated in Figure 3. Again, levels at Oakville were substantially lower than the remaining major stations.

## 3.2 Carbon Monoxide and Oxides of Nitrogen

The carbon monoxide (CO) concentrations monitored at 26 Breadalbane Street during the episode were higher than normal (2-3 fold) but far below the hourly and 8-hour criteria. The maximum 1-hour, 8-hour, and 24-hour average levels were 13 ppm (2300 EST, November 14, 1981), 8 ppm (2000 EST, November 14 - 0200 EST, November 15, 1981), and 6 ppm (November 14, 1981), respectively.

However, the CO level as measured at a street canyon and traffic corridor station (381 Yonge St., downtown Toronto) exceeded the 1-hour criterion of 30 ppm on one occasion (47 ppm at 0000 EST, November 15, 1981). The 8-hour criterion of 13 ppm was also exceeded during the episode. A concentration of 21 ppm was monitored between 2000 EST November 13 and 0300 EST November 14, and 27 ppm during the same time period on November 14-15, 1981.

For oxides of nitrogen ($NO_x$), the 24-hour average concentrations were 0.20 and 0.31 ppm respectively on November 13 and 14, 1981, higher than the monthly average of 0.075 ppm by 3-4 folds. The nitrogen dioxide ($NO_2$) levels did not exceed both the hourly and 24-hour average criteria of 0.20 ppm and 0.10 ppm, respectively. However, hourly nitric oxide (NO) concentration exceeded 0.20 ppm nineteen times over the episode, mostly late at night and in early mornings.

## 3.3 Hi-Vol and Dichotomous Filters

Hi-Vol and dichotomous filters were collected at the API station and analyzed for total suspended particulates and heavy metals.

Table 1 summarizes the total suspended particulates (TSP) and lead (Pb) levels across major hi-vol stations in Metropolitan Toronto. TSP concentrations on both November 13 and 14, 1981, exceeded 24-hour average criterion of 120 ug/m$^3$. Lead concentrations, although did not exceed the 24-hour criterion of 5 ug/m$^3$ (except Station 31082 : 5.3 ug/m$^3$), were substantially higher than normal.

Dichotomous sampler collects suspended particulates under 15 microns in size. The filter further separates the particles into coarse (2.5 to 15 microns) and fine (under 2.5 microns) portions. Data from during the episode is presented in Table 2. The total particulates collected on November 13, and 14, 1981 doubled the average concentrations as measured from the September 1980 - July 1981 study. The high fine particle level on November 14, 1981 might indicate a higher than normal lead concentration.

On November 13 and 14, 1981, the dichotomous sampler collected about 60% of the total suspended particulates as measured by the hi-vol. Dichotomous data also correlated well with soiling index in previous Studies.

### 3.4 Trend Across Air Monitoring Network

Figure 4 through Figure 9 illustrate the various air quality trends at different major continuous air monitoring stations. Examining the concentrations of several pollutants at the Toronto API station (31104) in Figure 4 indicated that the soiling index was the major factor in the high Index. Although sulphur dioxide and carbon monoxide levels were well below the desirable criteria, they, along with total hydrocarbon, showed extremely similar peaks during different stages of the episode.

The other two major Metropolitan Toronto stations, Kennedy/Lawrence in Scarborough (33003) and Evans/Arnold in Etobicoke (35033) detected comparable pollutant levels as shown in Figure 5 and 6, respectively. Ambient temperatures measured at both stations were in extreme agreement with each other.

The Ritson Road station in Oshawa (45025) showed similar air quality patterns (Figure 7). The soiling index, however, had higher maximum than the other stations but for a shorter time interval.

The Oakville station (44015) was the only location among others whose API did not reach 32. In fact, it never surpassed 20 as shown in Figure 8. The various pollutant levels were low as expected.

A quick scan at the downtown Hamilton station (29025) in Figure 9 demonstrates that the soiling index was rather consistently high. Consequently, the API fluctuated to a lesser degree than the Toronto stations.

## 3.5 Sources of Episode

### 3.5.1 - Automobile Emission

In addition to the poor dispersion of air pollutants due to the strong temperature inversion and stagnant wind conditions, one of the major sources of the episode is vehicle emission.

Higher than normal carbon monoxide (CO) levels were detected at Yonge/Gerrard Streets in downtown Toronto. The 8-hour criterion of 13 ppm was exceeded twice during the period 2000-0300 hours. The 8-hour average was 21 ppm for the November 13-14 time period and 27 ppm for November 14-15.

Automobile exhausts, among others, are major sources for the oxides of nitrogen ($NO_x$) and lead. Increased concentrations of these pollutants were recorded.

Traffic volume in the downtown core (Figure 10) was high during the episode due to such activities as Christmas shopping and sporting events. The 1981 traffic data for the downtown Cordon (Table 3) showed that the total number of vehicles per weekday is approximately 150,000, both for inbound and outbound traffic.

### 3.5.2 - Industries

As the episode occurred on a weekend, most industries were either shut down or operating at a reduced rate, as in the case of Ontario Hydro and the Metro incinerators. A few others were running on natural gas.

Ontario Hydro, a key contributor to sulphur dioxide ($SO_2$) levels in the Metropolitan Toronto area (approximately 70%), was operating at reduced dates. Lakeview Generating Station had two units down and Hearn Generating Station was not operating. Metro incinerators such as Commissioner Street and Dufferin Street were shut down as well. Consequently, low $SO_2$ levels were monitored throughout the episode.

Several contributing sources, which included Maple Leaf Mills, Bishop Building Materials, and the University of Toronto, were not in operation. Some others such as Kodak, Canada Packers, Canadian Forces Base, and the Toronto Hospital Corporation were on natural gas. Thus, their contribution appeared to be insignificant.

### 3.5.3 - Long Range Transports

A wind trajectory for the southern Great Lake Region is presented in Figure 11. A sweeping wind pattern, along the south shores of Lake Ontario and Lake Erie, was observed. Although a long range transport of certain air pollutants appeared prominent, the low sulphur dioxide levels across the monitoring network has suggested otherwise.

Moreover, the API at Oakville never exceeded 20 and concentrations of other pollutants were low as well. Thus, localized sources might have played a more significant role than long range transport.

## 4. Meteorological Data Analysis

### 4.1 Surface Weather Map

Stagnant wind conditions and a strong temperature inversion were major factors in this air pollution episode. Inspection of the surface weather maps from November 12 to 15, 1981 (Appendix B) indicated there was a constant high pressure system over the Lake Ontario region.

On November 13 and 14, 1981, there was very little movement of the high pressure system's centre. Windspeed had decreased significantly from the 12th and wind conditions became stagnant, resulting in little or no dispersal of air pollutants.

On November 15, 1981, a low pressure system began to move in from the east coast. Wind velocities were increased which enhanced the dispersal of contaminants.

### 4.2 Roles of Wind & Temperature

Examination of the hourly wind data from various meteorological stations indicates very little movement at the first/lower level. The wind conditions in Toronto and Hamilton were stagnant, particularly at the level one (33-40 feet). It was more prominent at the Oshawa station, resulting in a prolonged period of high Soiling Index readings with little fluctuations.

On the other hand, Oakville experienced a shorter period of low wind speed, thus resulted in slightly better scattering of air pollutants.

Difference in temperature is illustrated in Figure 12 for the two Toronto stations. Both displayed similar peaks and troughs. The peaks occurred when temperature actually increased with height and the troughs were results of a lake breeze effect.

Plotting the temperature data from Etobicoke and the CN tower against height (Figure 13), shows that temperature tends to increase with height. Inversions occurred at approximately 300 feet and 1500 feet.

A similar temperature pattern was observed in Buffalo (Figure 14) where an inversion took place at approximately 2000 feet.

## 5. Conclusions

The November 13-15, 1981 air pollution episode resulted from strong temperature inversions and stagnant wind conditions. These are unfavourable yet uncontrollable weather conditions which provide very little vertical mixing and poor dispersal of air pollutants.

Major industrial sources were not operating during the episode. Localized sources such as automobile emissions appeared to be the main contributors. Higher than normal carbon monoxide, lead, and oxides of nitrogen levels were detected.

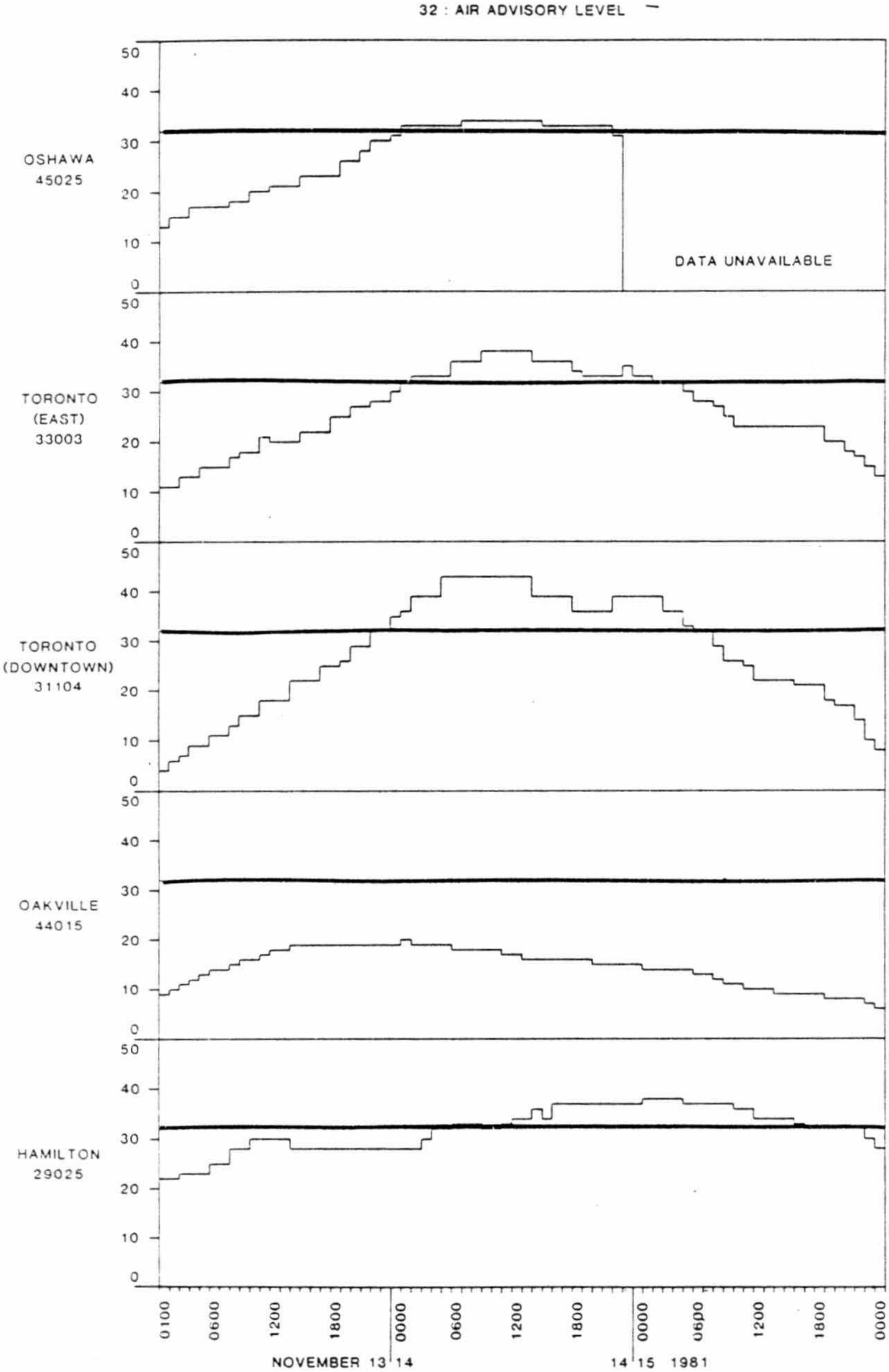
Suspended particulate matter rather than sulphur dioxide played a major role in the high air pollution index (API). The API exceeded the Air Advisory Level of 32 for a total of 30 hours, but never reached the First Air Pollution Alert of 50.

# FIGURES

## 1 TO 14

## Figure 1

AIR POLLUTION INDEX (NOVEMBER 13-15/81)



## Figure 2

## SULPHUR DIOXIDE

## NOVEMBER 13-15/81

UNIT: ppm

CRITERIA: 0.25 (1 HOUR), 0.10 (24 HOURS), 0.02 (1 YEAR)

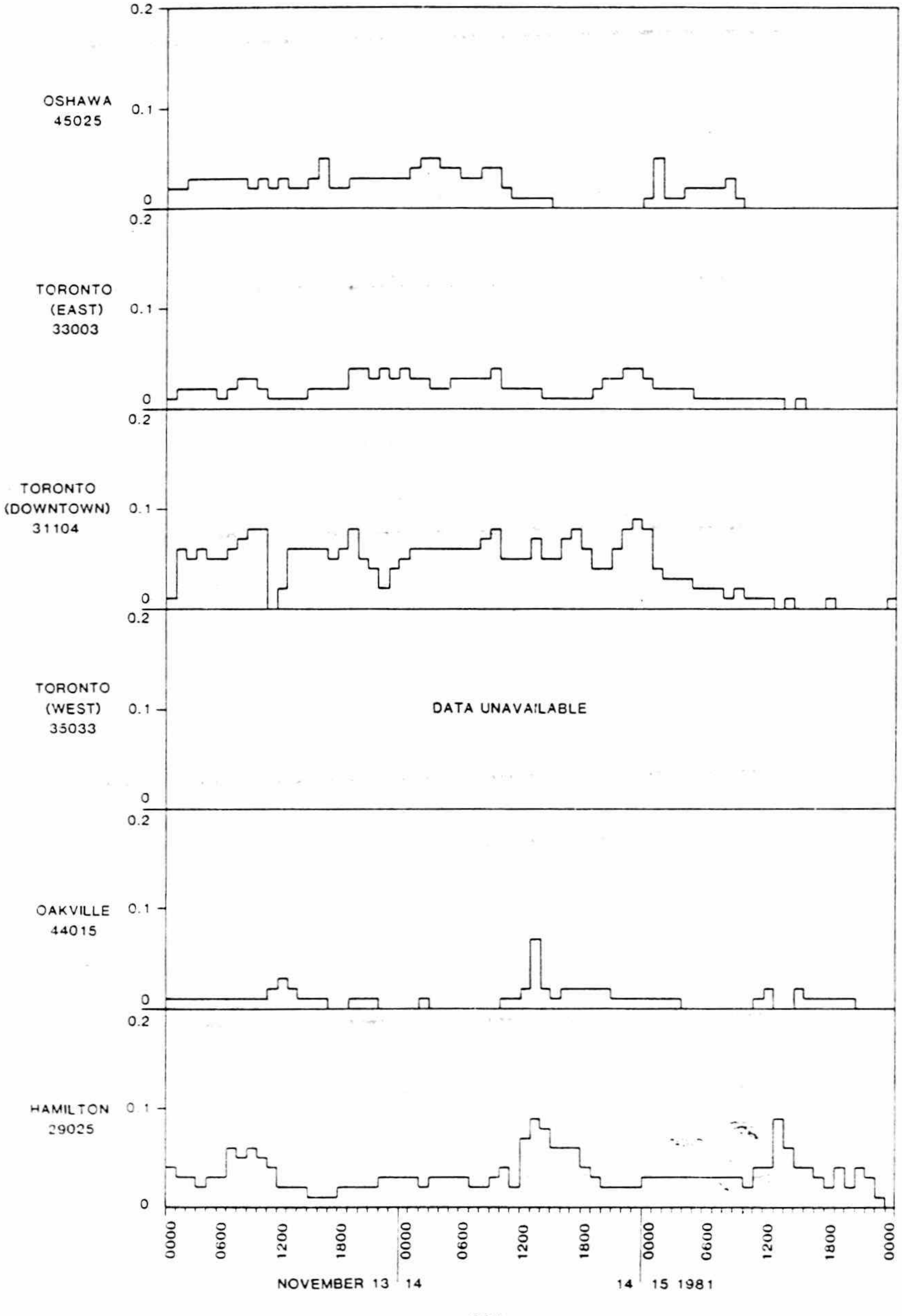


Figure 3

SOILING INDEX-COEFFICIENT OF HAZE
NOVEMBER 13-15/81

UNIT COH/1000 FEET OF AIR

CRITERIA 1.0(24 HOURS),0.5(1 YEAR)

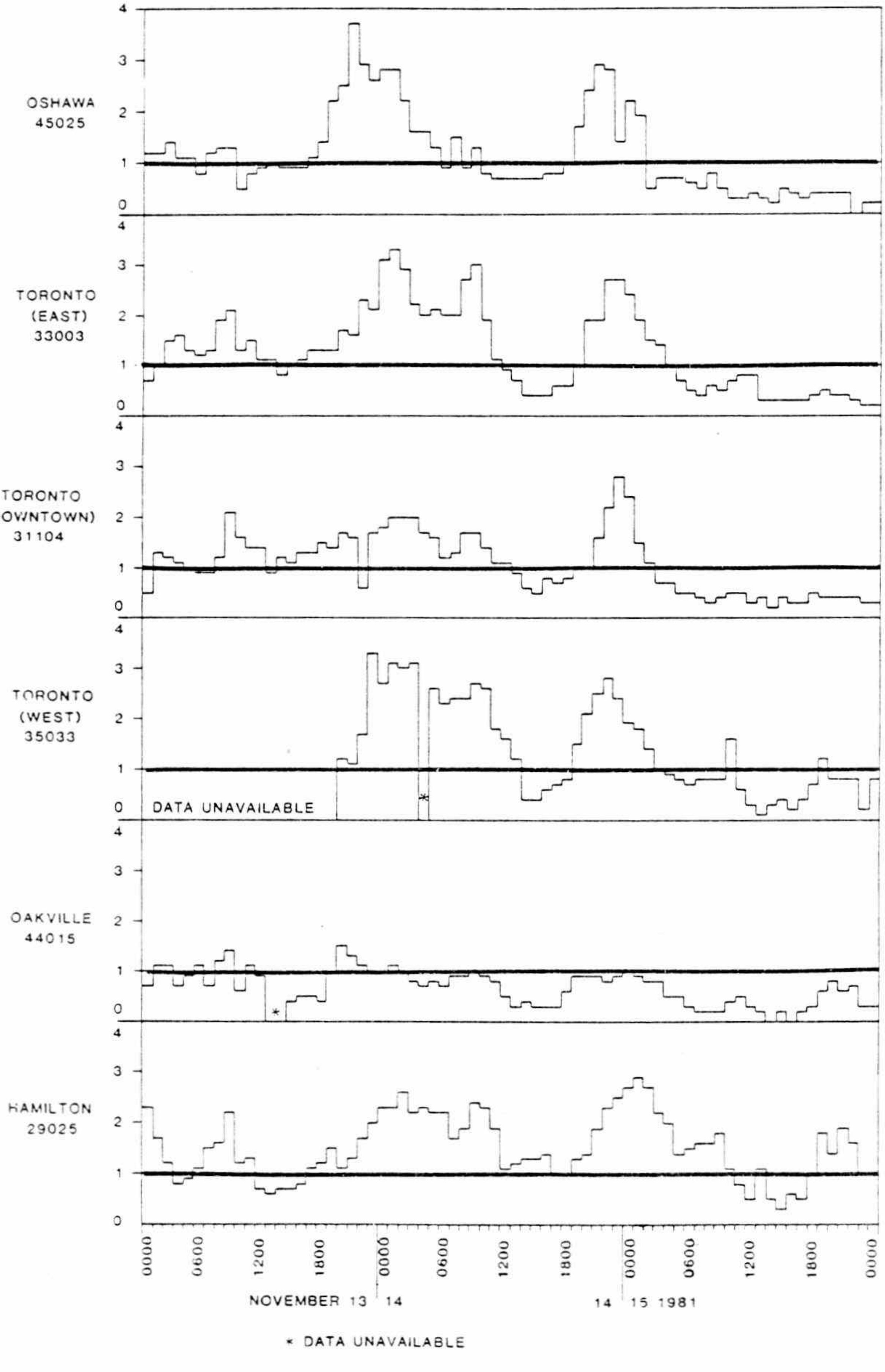
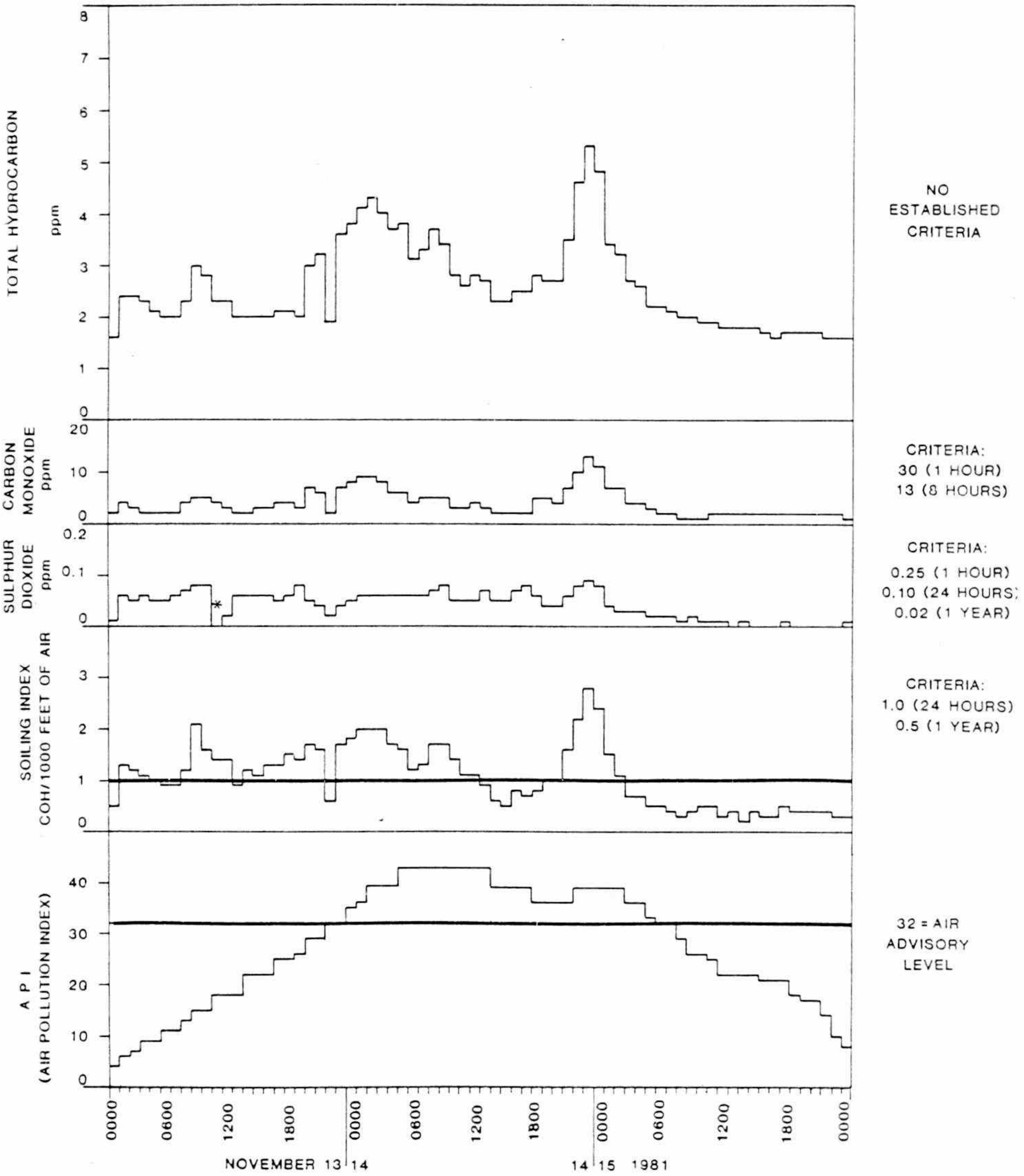


Figure 4

AIR POLLUTION TRENDS AT STATION 31104- NOVEMBER 13-15/81

26 BREADALBANE ST., DOWNTOWN TORONTO

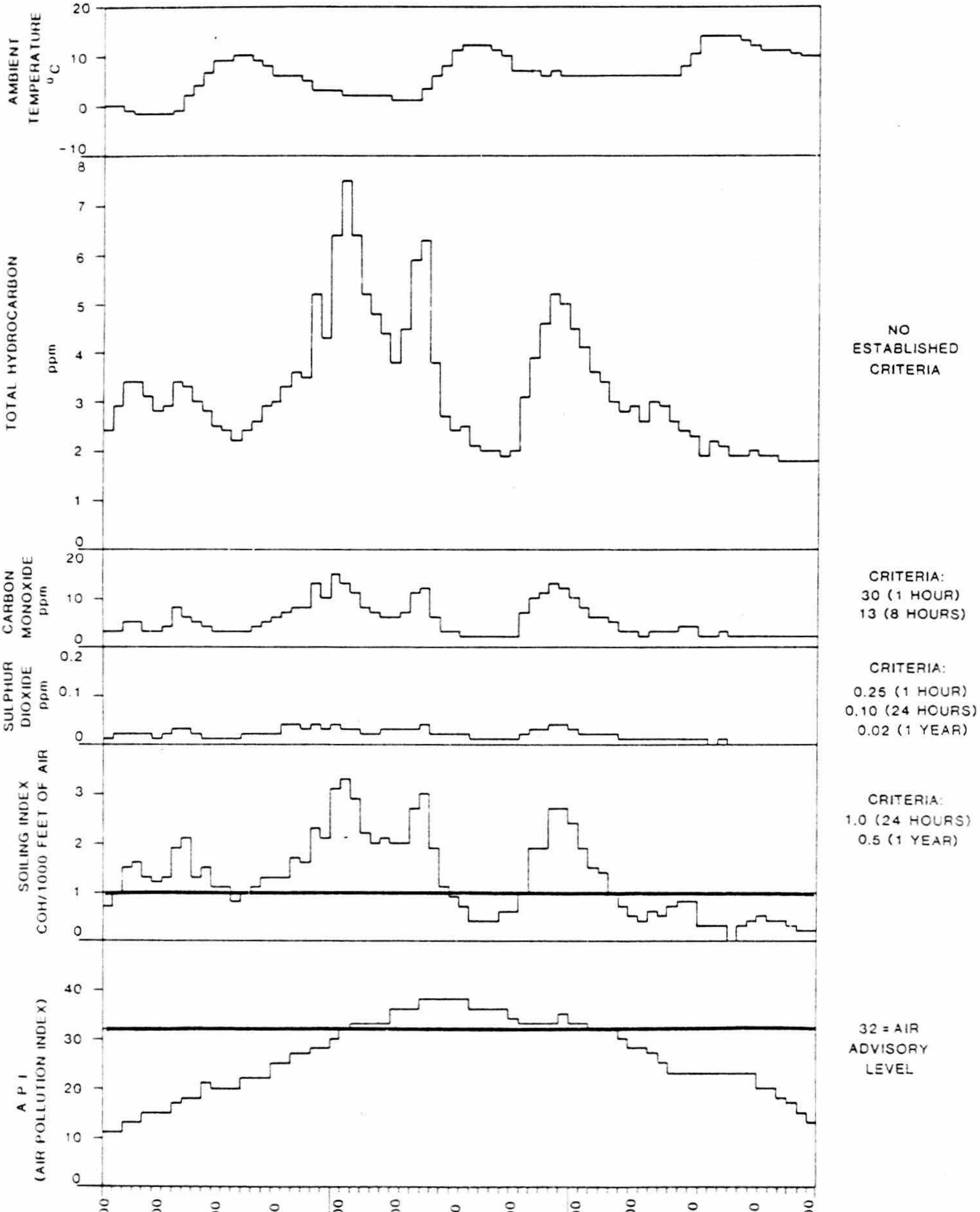


* DATA UNAVAILABLE

Figure 5

AIR POLLUTION TRENDS AT STATION 33003-NOVEMBER 13-15/81

KENNEDY ROAD/LAWRENCE AVE., SCARBOROUGH



## Figure 6

## AIR POLLUTION TRENDS AT STATION 35033-NOVEMBER 13-15/81

EVANS AVE./ARNOLD ST., ETOBICOKE

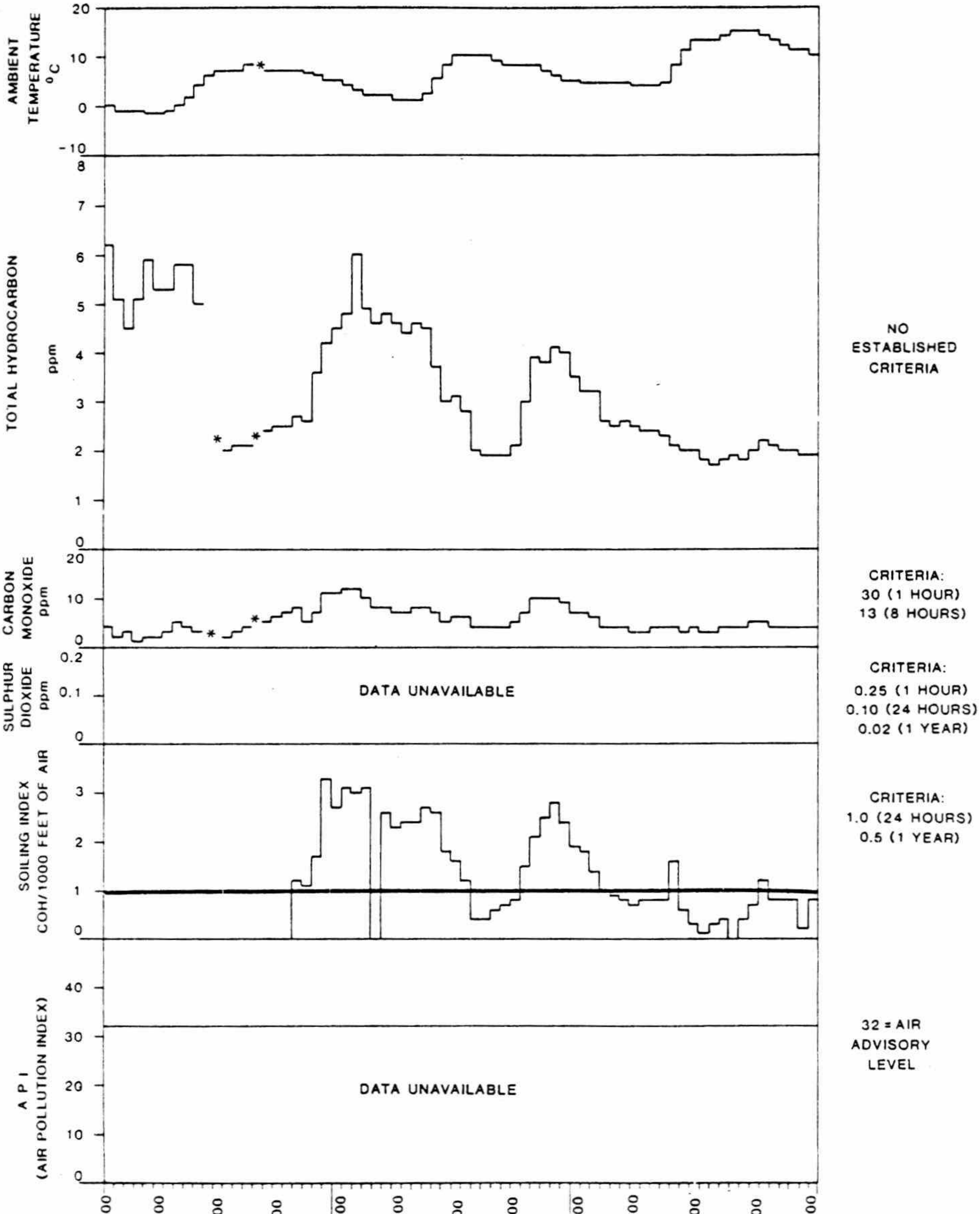


Figure 7

AIR POLLUTION TRENDS AT STATION 45025-NOVEMBER 13-15/81

RITSON ROAD/OLIVE AVE., OSHAWA

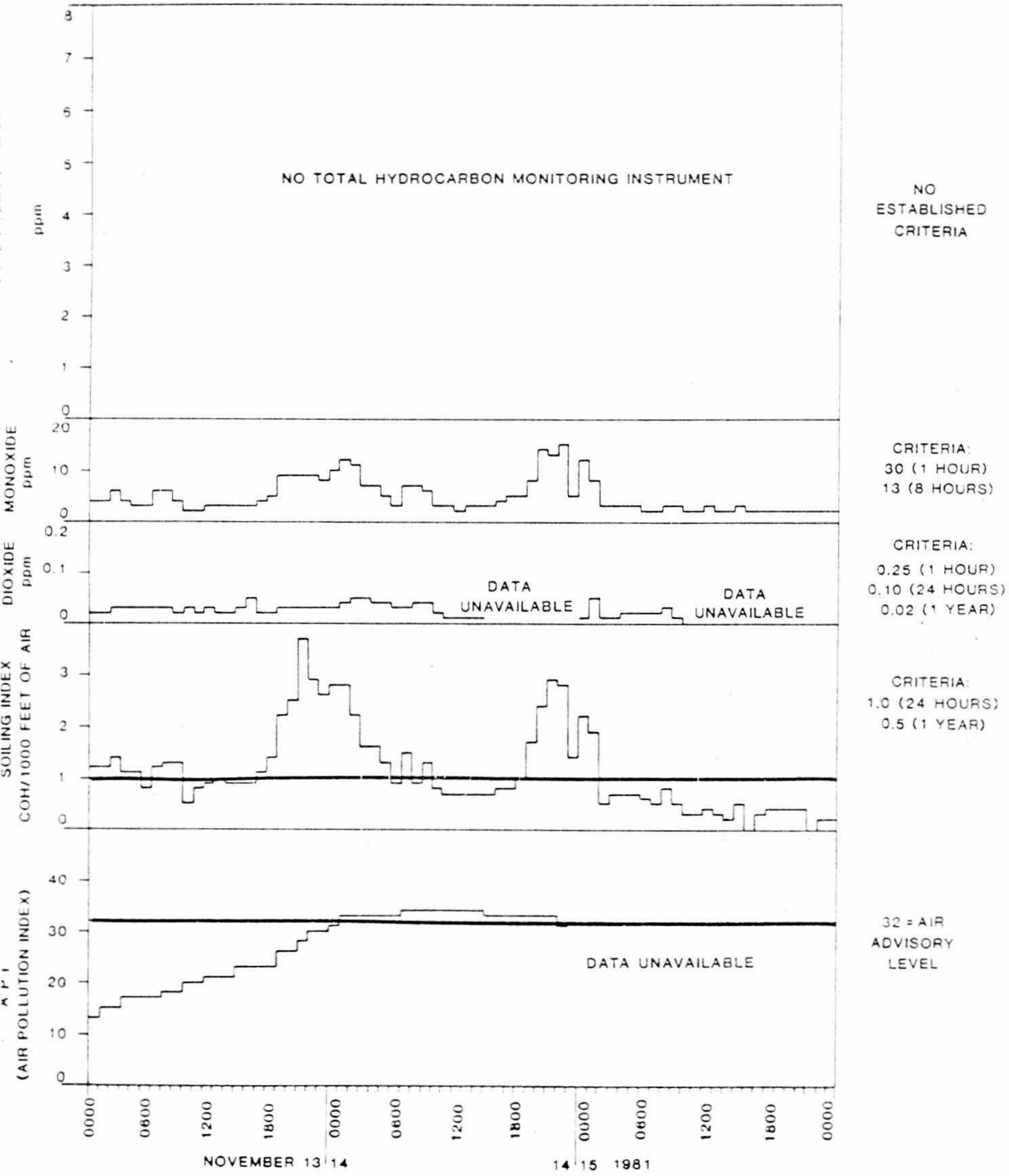


Figure 8

AIR POLLUTION TRENDS AT STATION 44015-NOVEMBER 13-15/81

BRONTE ROAD/WOBURN CR., OAKVILLE

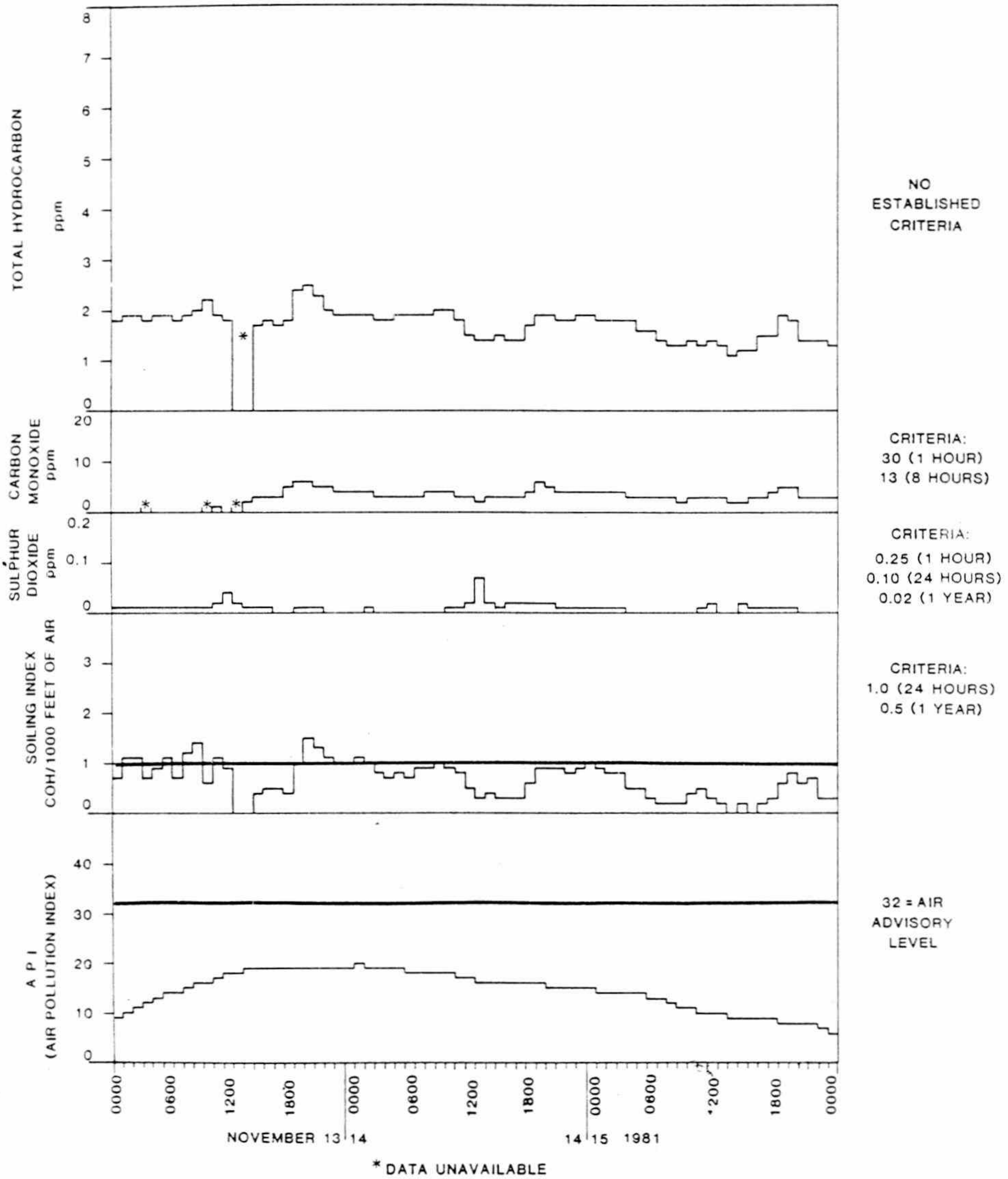
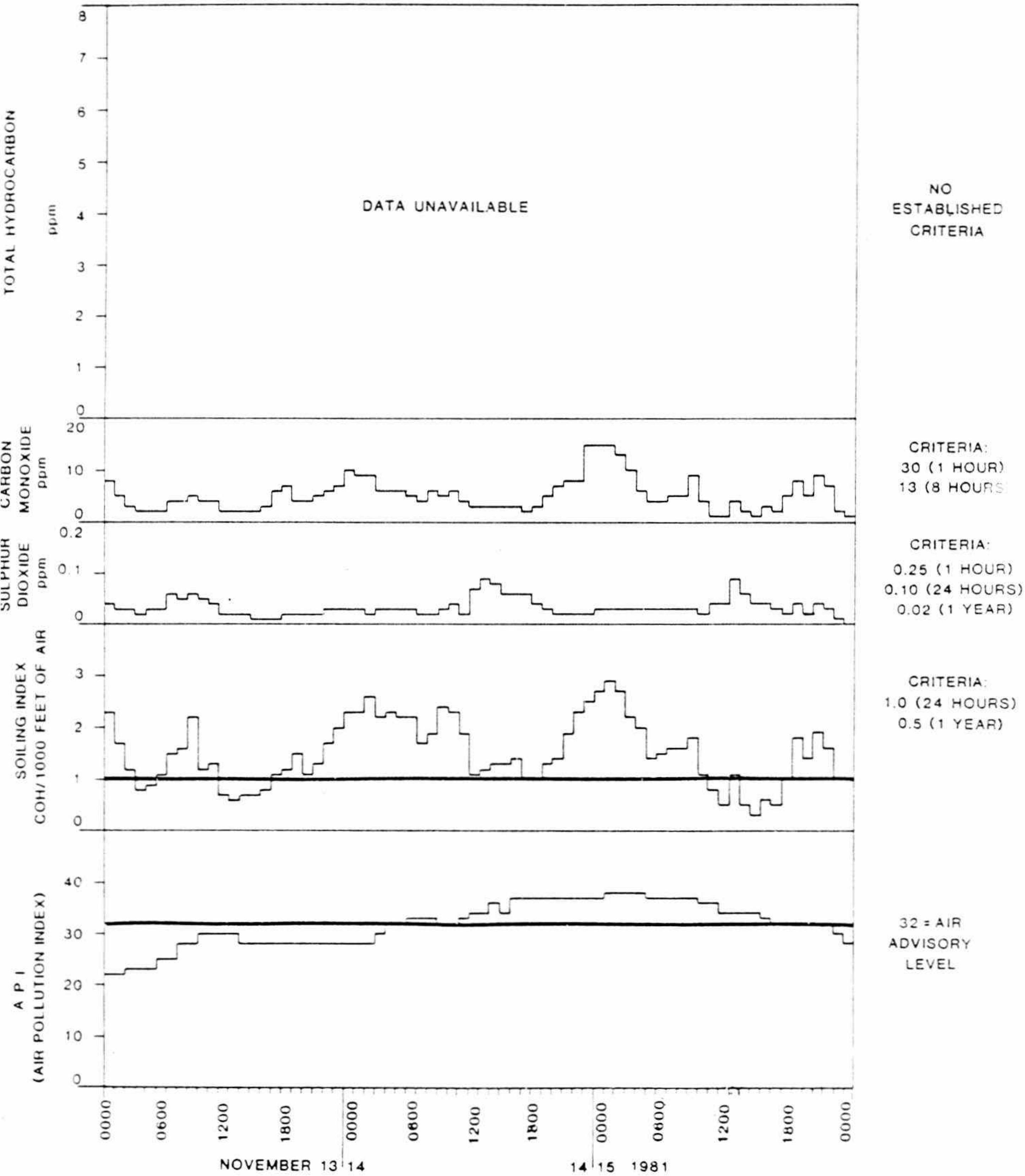


Figure 9

AIR POLLUTION TRENDS AT STATION 29025-NOVEMBER 13-15/81

BARTON/WENTWORTH, DOWNTOWN HAMILTON



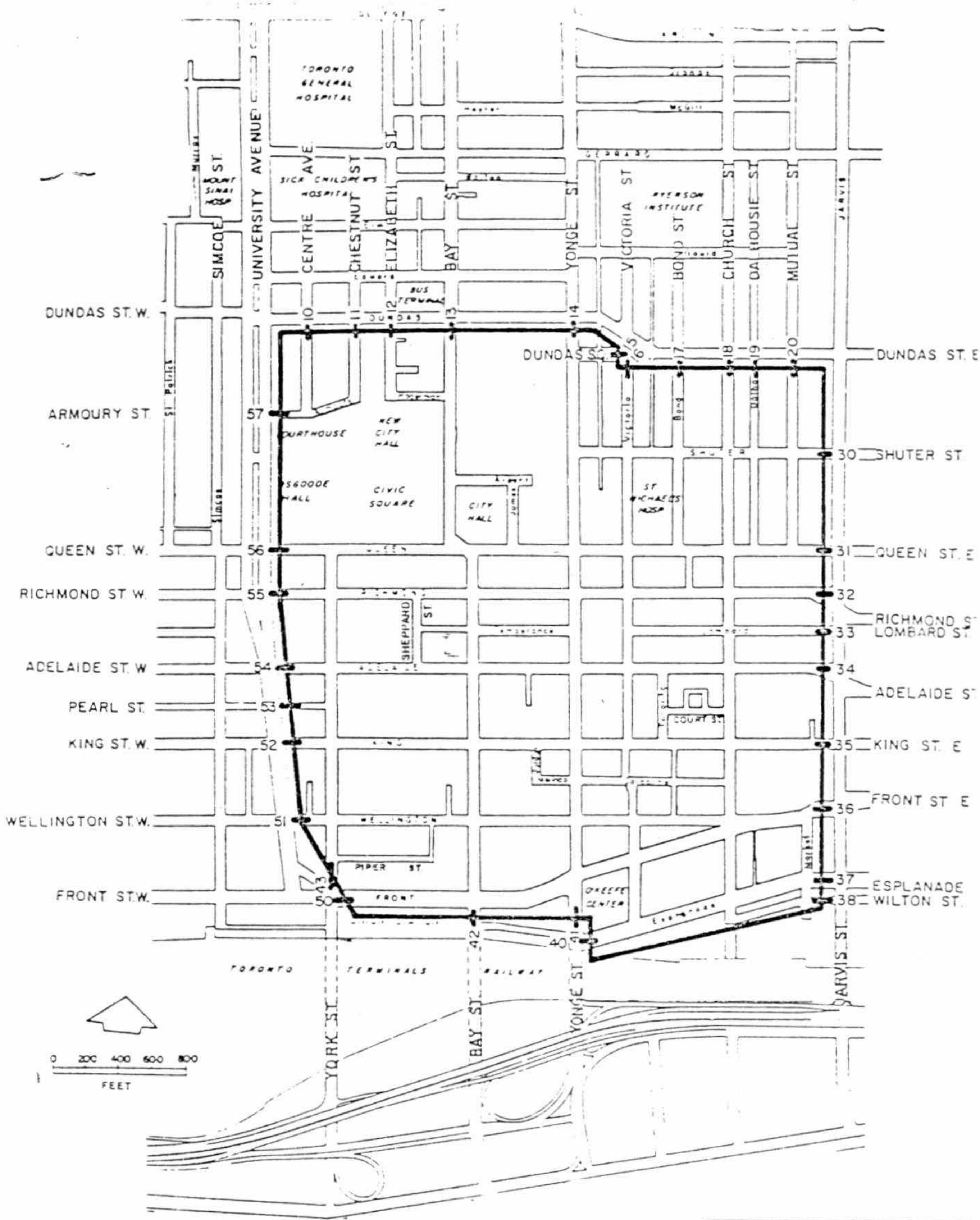
NO
ESTABLISHED
CRITERIA

CRITERIA:
30 (1 HOUR)
13 (8 HOURS)

CRITERIA:
0.25 (1 HOUR)
0.10 (24 HOURS)
0.02 (1 YEAR)

CRITERIA:
1.0 (24 HOURS)
0.5 (1 YEAR)

32 = AIR
ADVISORY
LEVEL



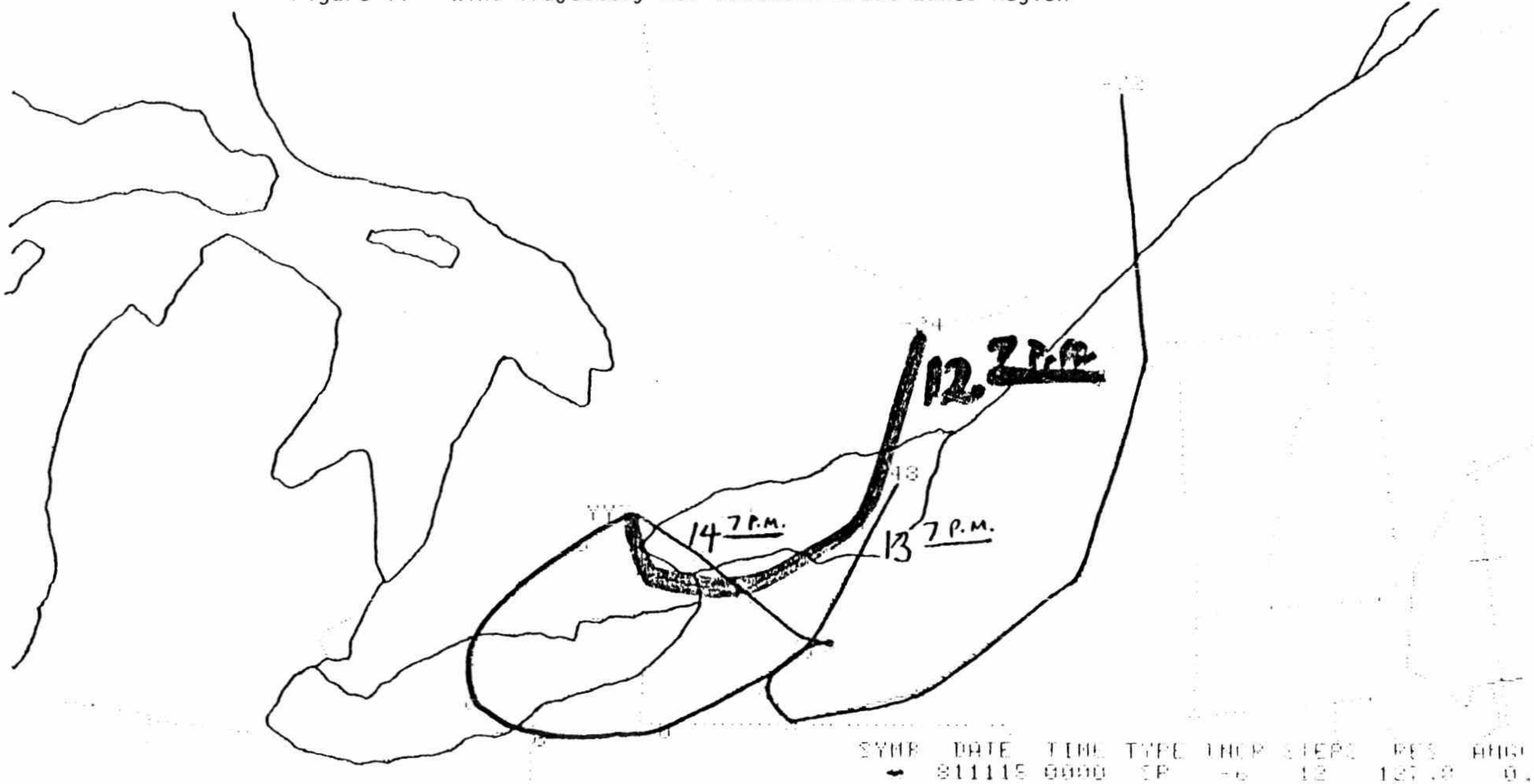
CITY OF TORONTO
DEPT. OF PUBLIC WORKS
TRAFFIC ENGINEERING SECTION

DOWNTOWN CORE CORDON
STATION LOCATIONS

REVISED: FEB 1973 DEC.

FIGURE 10

Figure 11 Wind Trajectory for Southern Great Lakes Region



| SYMB | DATE | TIME | TYPE | INCR | STEPS | RES | ANGL | VEL |
|---|---|---|---|---|---|---|---|---|
| ━ | 811115 | 0000 | SP | -6 | 12 | 127.0 | 0. | 1.00 |
| ━ | 811114 | 0000 | SP | -6 | 8 | 127.0 | 0. | 1.00 |
| ● | 811113 | 0000 | SP | -6 | 4 | 127.0 | 0. | 1.00 |

Figure 12

VERTICAL TEMPERATURE DIFFERENCE (°C)
(NOVEMBER 13-15/81)

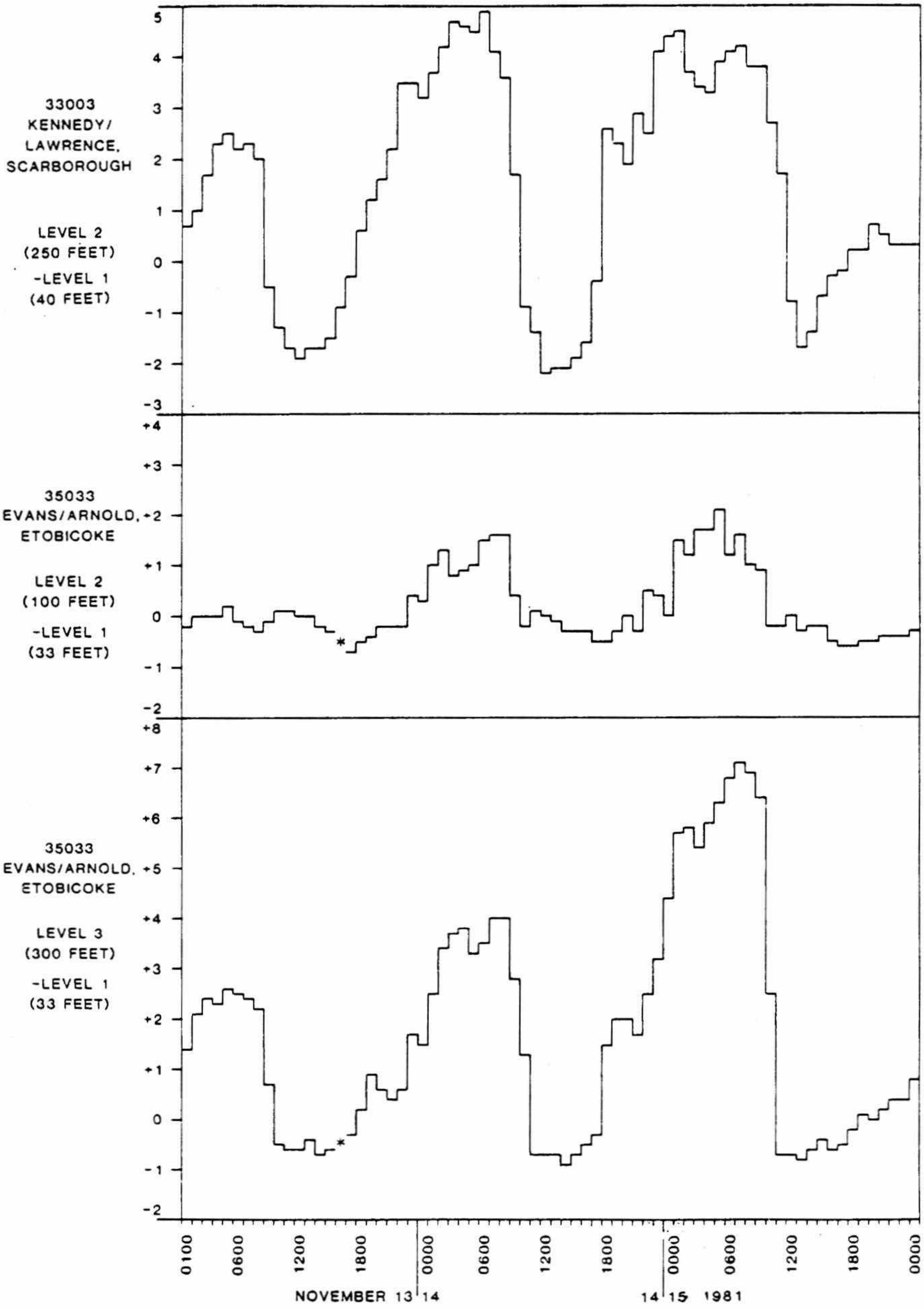


Figure 13 Temperature Inversion Plot -Toronto

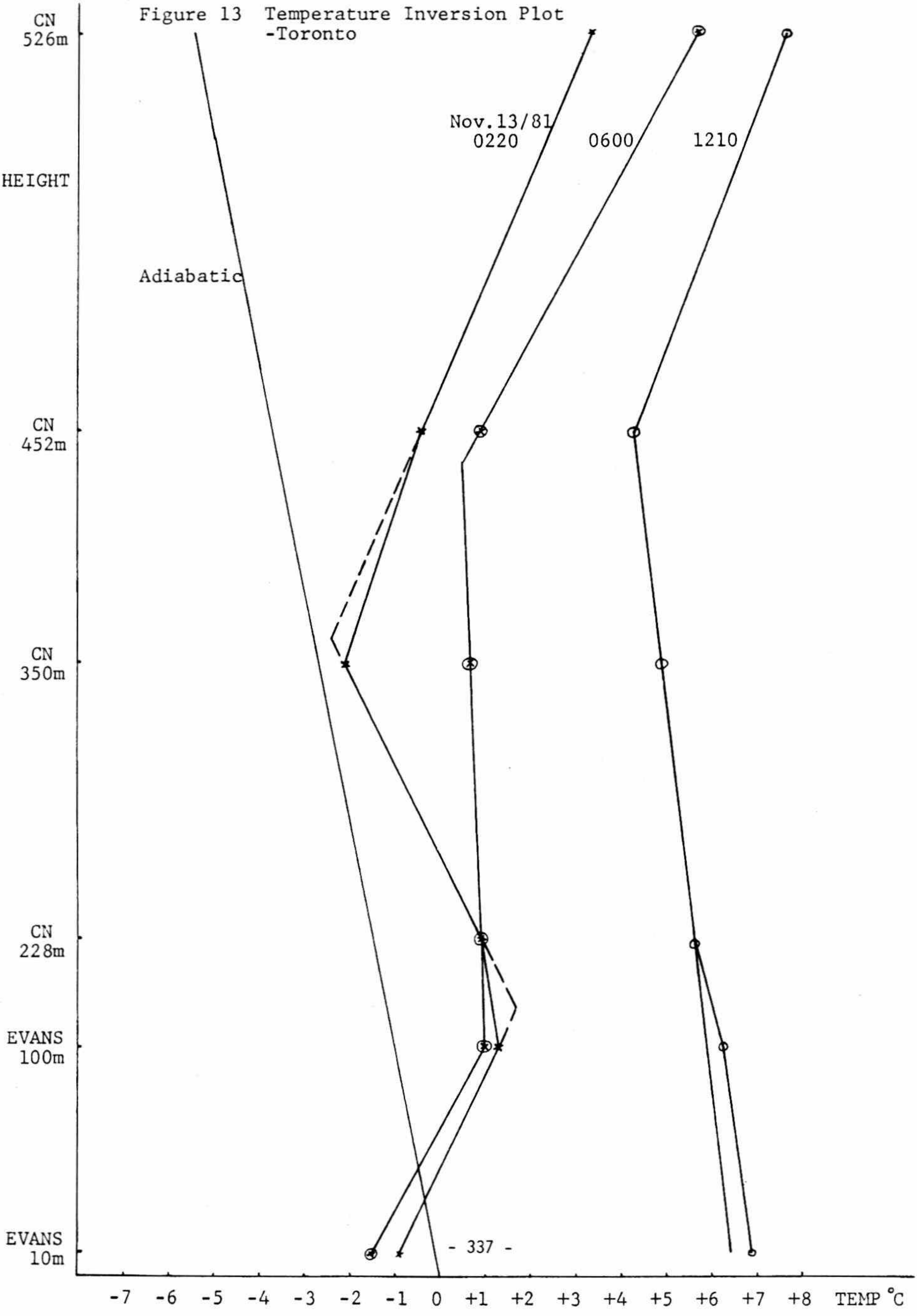
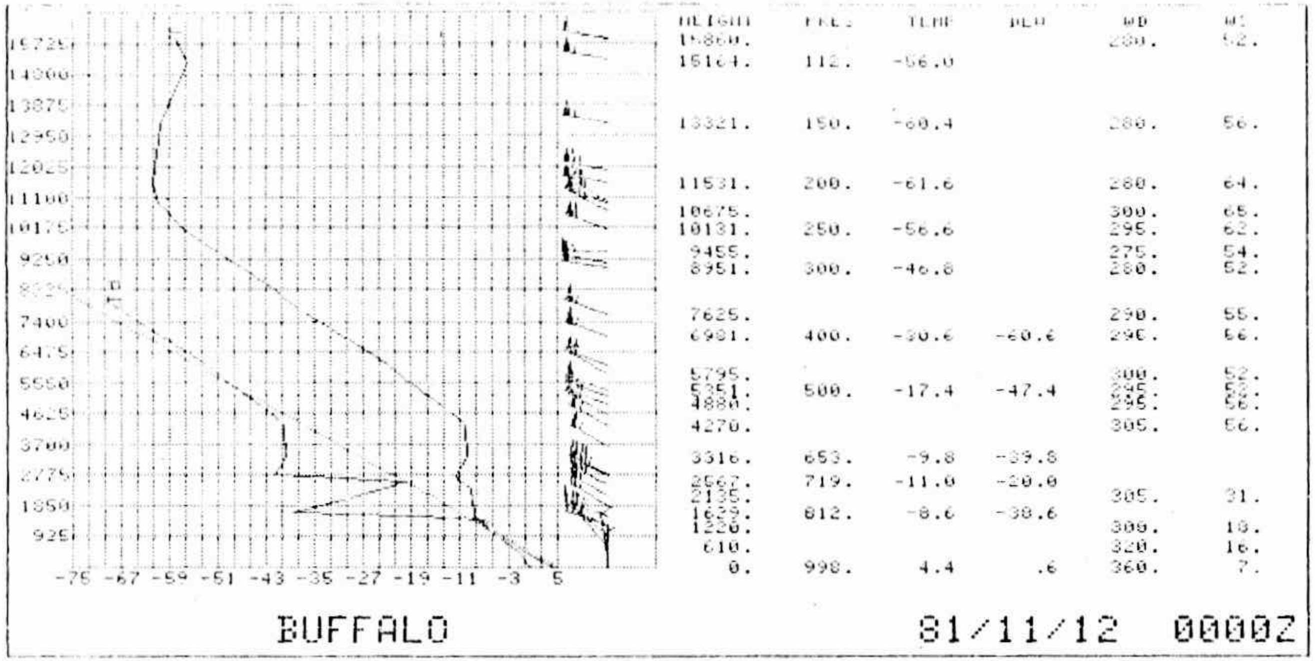
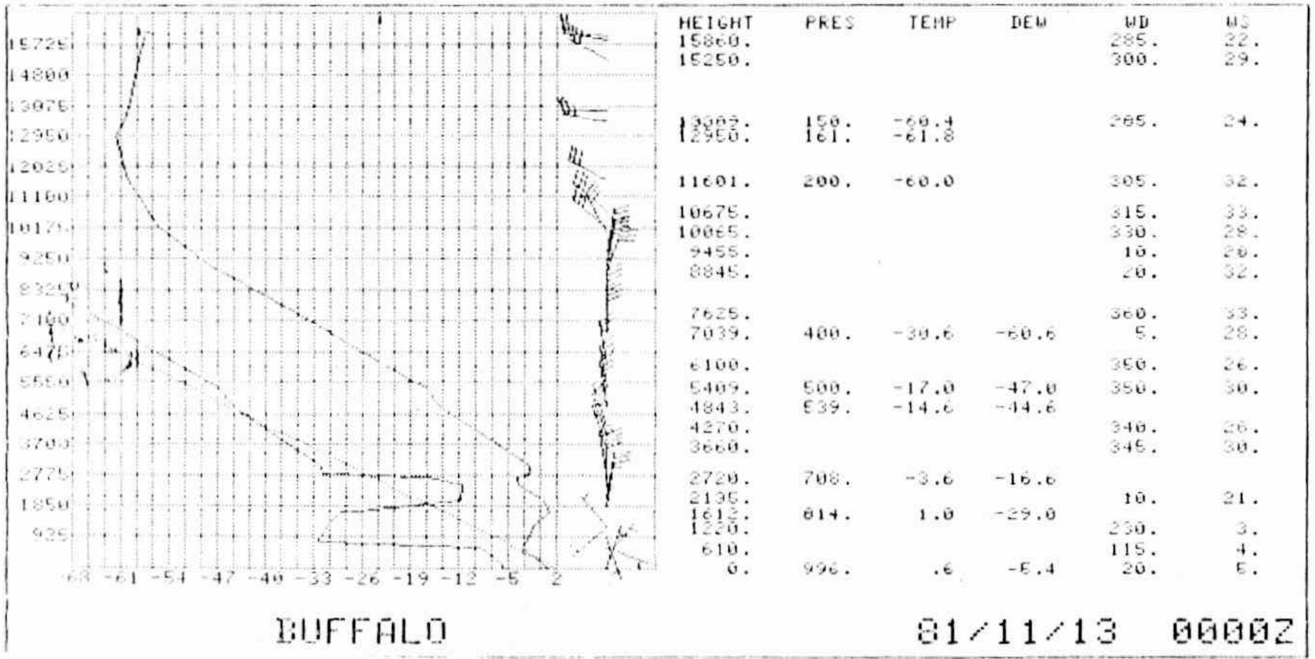


Figure 14 Temperature Inversion Plots - Buffalo



| HEIGHT | PRES | TEMP | DEW | WD | WS |
|---|---|---|---|---|---|
| 15860. | | | | 280. | 52. |
| 15164. | 112. | -56.0 | | | |
| 13321. | 150. | -60.4 | | 280. | 56. |
| 11531. | 200. | -61.6 | | 280. | 64. |
| 10675. | | | | 300. | 65. |
| 10131. | 250. | -56.6 | | 295. | 62. |
| 9455. | | | | 275. | 54. |
| 8951. | 300. | -46.8 | | 280. | 52. |
| 7625. | | | | 290. | 55. |
| 6981. | 400. | -30.6 | -60.6 | 290. | 56. |
| 5795. | | | | 300. | 52. |
| 5351. | 500. | -17.4 | -47.4 | 295. | 52. |
| 4880. | | | | 295. | 56. |
| 4270. | | | | 305. | 56. |
| 3316. | 653. | -9.8 | -39.8 | | |
| 2567. | 719. | -11.0 | -20.0 | | |
| 2135. | | | | 305. | 31. |
| 1629. | 812. | -8.6 | -38.6 | | |
| 1220. | | | | 300. | 18. |
| 610. | | | | 320. | 16. |
| 0. | 998. | 4.4 | .6 | 360. | 7. |

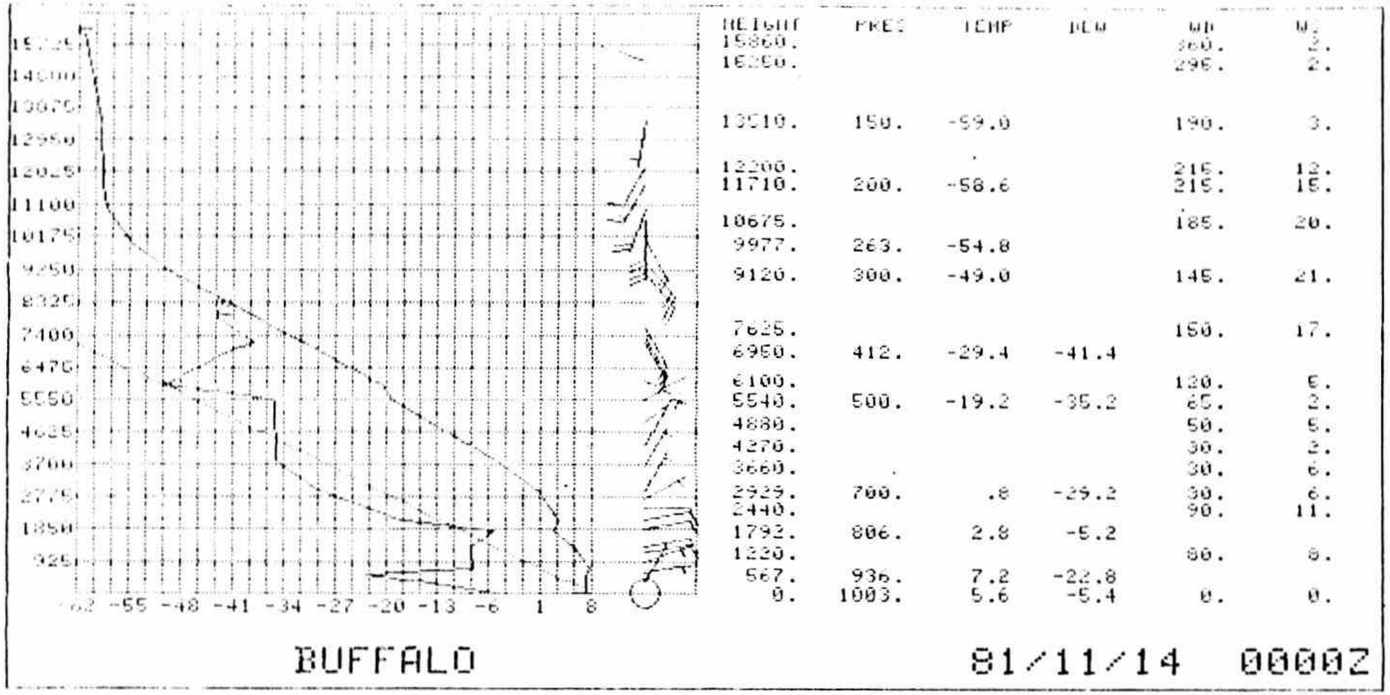
81/11/12 0000Z



| HEIGHT | PRES | TEMP | DEW | WD | WS |
|---|---|---|---|---|---|
| 15860. | | | | 285. | 22. |
| 15250. | | | | 300. | 29. |
| 13002. | 150. | -60.4 | | 285. | 24. |
| 12950. | 161. | -61.8 | | | |
| 11601. | 200. | -60.0 | | 305. | 32. |
| 10675. | | | | 315. | 33. |
| 10065. | | | | 330. | 28. |
| 9455. | | | | 10. | 20. |
| 8845. | | | | 20. | 32. |
| 7625. | | | | 360. | 33. |
| 7039. | 400. | -30.6 | -60.6 | 5. | 28. |
| 6100. | | | | 350. | 26. |
| 5409. | 500. | -17.0 | -47.0 | 350. | 30. |
| 4843. | 539. | -14.6 | -44.6 | | |
| 4270. | | | | 340. | 26. |
| 3660. | | | | 345. | 30. |
| 2720. | 708. | -3.6 | -16.6 | | |
| 2135. | | | | 10. | 21. |
| 1612. | 814. | 1.0 | -29.0 | | |
| 1220. | | | | 230. | 3. |
| 610. | | | | 115. | 4. |
| 0. | 996. | .6 | -5.4 | 20. | 5. |

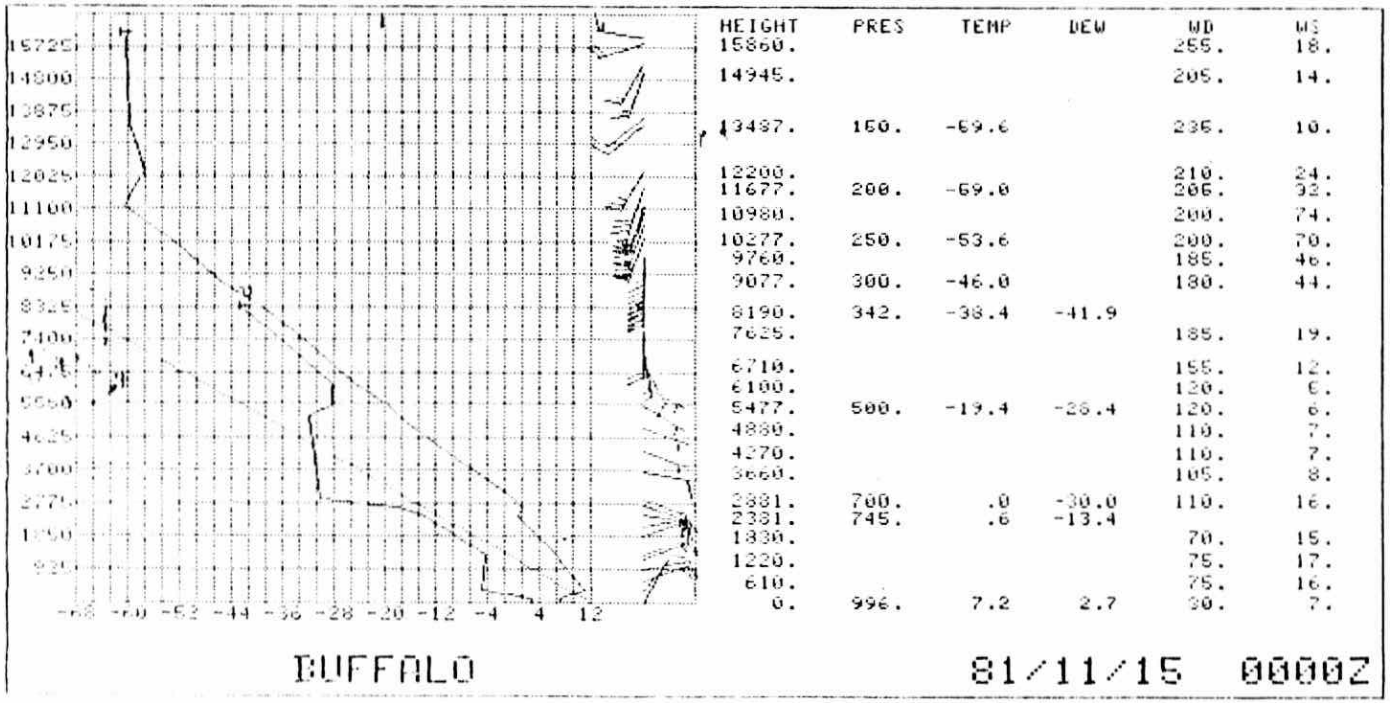
81/11/13 0000Z

Figure 14 (Cont'd)



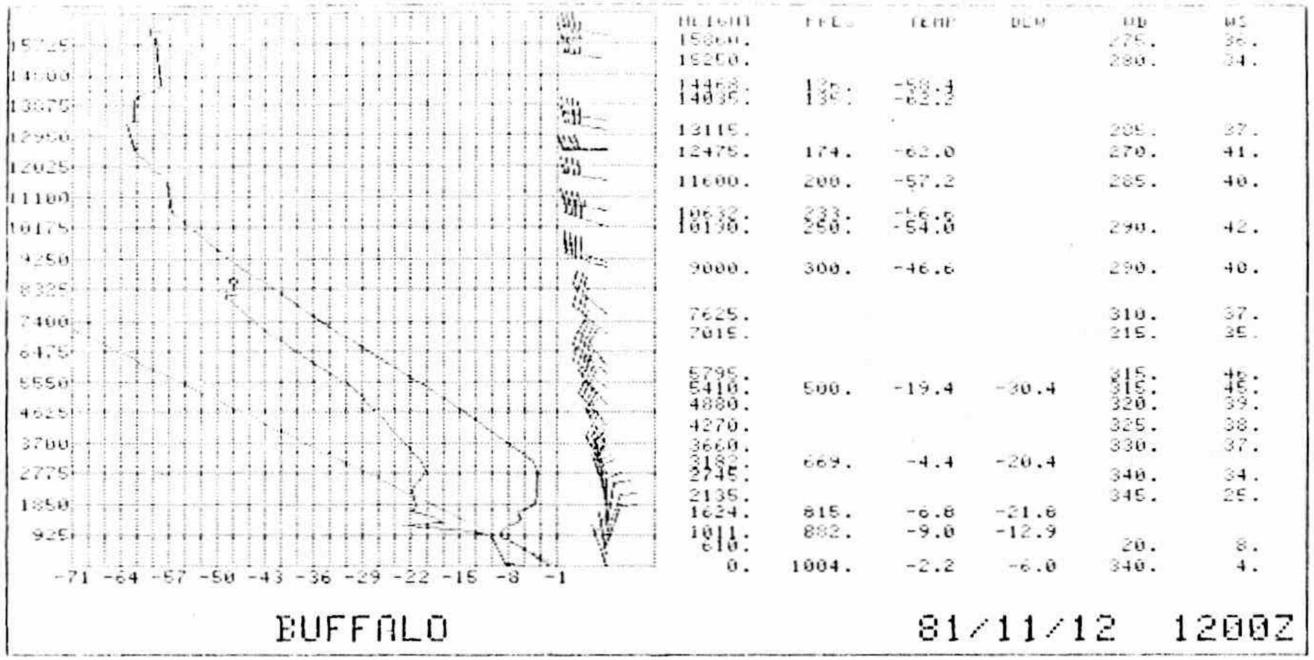
| HEIGHT | PRES | TEMP | DEW | WD | WS |
|---|---|---|---|---|---|
| 15860. | | | | 360. | 2. |
| 16250. | | | | 296. | 2. |
| 13510. | 150. | -59.0 | | 190. | 3. |
| 12200. | | | | 216. | 12. |
| 11710. | 200. | -58.6 | | 215. | 15. |
| 10675. | | | | 185. | 20. |
| 9977. | 263. | -54.8 | | | |
| 9120. | 300. | -49.0 | | 145. | 21. |
| 7625. | | | | 160. | 17. |
| 6950. | 412. | -29.4 | -41.4 | | |
| 6100. | | | | 120. | 6. |
| 5540. | 500. | -19.2 | -35.2 | 65. | 2. |
| 4880. | | | | 50. | 5. |
| 4270. | | | | 30. | 2. |
| 3660. | | | | 30. | 6. |
| 2929. | 700. | .8 | -29.2 | 30. | 6. |
| 2440. | | | | 90. | 11. |
| 1792. | 806. | 2.8 | -5.2 | | |
| 1220. | | | | 80. | 8. |
| 567. | 936. | 7.2 | -22.8 | | |
| 0. | 1003. | 5.6 | -5.4 | 0. | 0. |

BUFFALO 81/11/14 0000Z



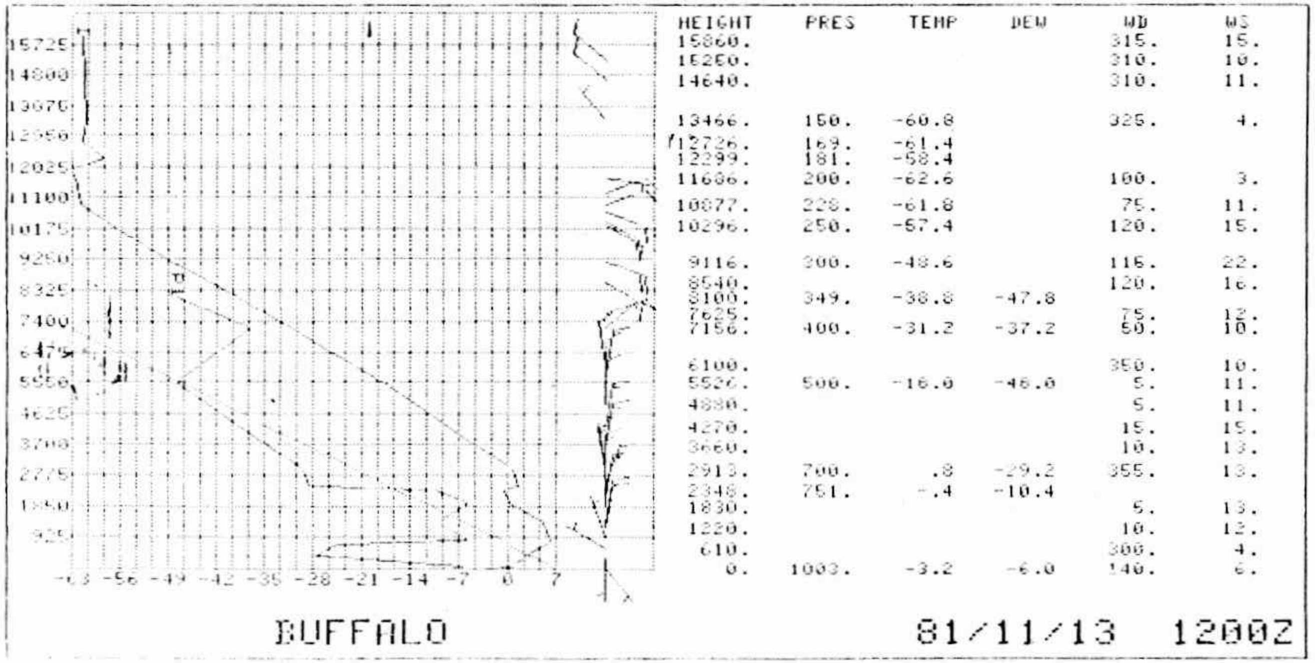
| HEIGHT | PRES | TEMP | DEW | WD | WS |
|---|---|---|---|---|---|
| 15860. | | | | 255. | 18. |
| 14945. | | | | 205. | 14. |
| 13487. | 150. | -69.6 | | 236. | 10. |
| 12200. | | | | 210. | 24. |
| 11677. | 200. | -69.0 | | 206. | 32. |
| 10980. | | | | 200. | 74. |
| 10277. | 250. | -53.6 | | 200. | 70. |
| 9760. | | | | 185. | 46. |
| 9077. | 300. | -46.0 | | 180. | 44. |
| 8190. | 342. | -38.4 | -41.9 | | |
| 7625. | | | | 185. | 19. |
| 6710. | | | | 155. | 12. |
| 6100. | | | | 120. | 6. |
| 5477. | 500. | -19.4 | -26.4 | 120. | 6. |
| 4880. | | | | 110. | 7. |
| 4270. | | | | 110. | 7. |
| 3660. | | | | 105. | 8. |
| 2881. | 700. | .0 | -30.0 | 110. | 16. |
| 2381. | 745. | .6 | -13.4 | | |
| 1830. | | | | 70. | 15. |
| 1220. | | | | 75. | 17. |
| 610. | | | | 75. | 16. |
| 0. | 996. | 7.2 | 2.7 | 30. | 7. |

BUFFALO 81/11/15 0000Z



| HEIGHT | PRES | TEMP | DEW | WD | WS |
|---|---|---|---|---|---|
| 15860. | | | | 275. | 36. |
| 15250. | | | | 280. | 34. |
| 14468. | 136. | -58.4 | | | |
| 14036. | 139. | -62.2 | | | |
| 13115. | | | | 205. | 37. |
| 12475. | 174. | -62.0 | | 270. | 41. |
| 11600. | 200. | -57.2 | | 285. | 40. |
| 10632. | 233. | -56.6 | | | |
| 10130. | 250. | -54.0 | | 290. | 42. |
| 9000. | 300. | -46.6 | | 290. | 40. |
| 7625. | | | | 310. | 37. |
| 7015. | | | | 215. | 35. |
| 5795. | | | | 315. | 46. |
| 5410. | 500. | -19.4 | -30.4 | 315. | 45. |
| 4880. | | | | 320. | 39. |
| 4270. | | | | 325. | 38. |
| 3660. | | | | 330. | 37. |
| 3182. | 669. | -4.4 | -20.4 | | |
| 2745. | | | | 340. | 34. |
| 2135. | | | | 345. | 25. |
| 1624. | 815. | -6.8 | -21.6 | | |
| 1011. | 882. | -9.0 | -12.9 | | |
| 610. | | | | 20. | 8. |
| 0. | 1004. | -2.2 | -6.0 | 340. | 4. |

BUFFALO 81/11/12 1200Z

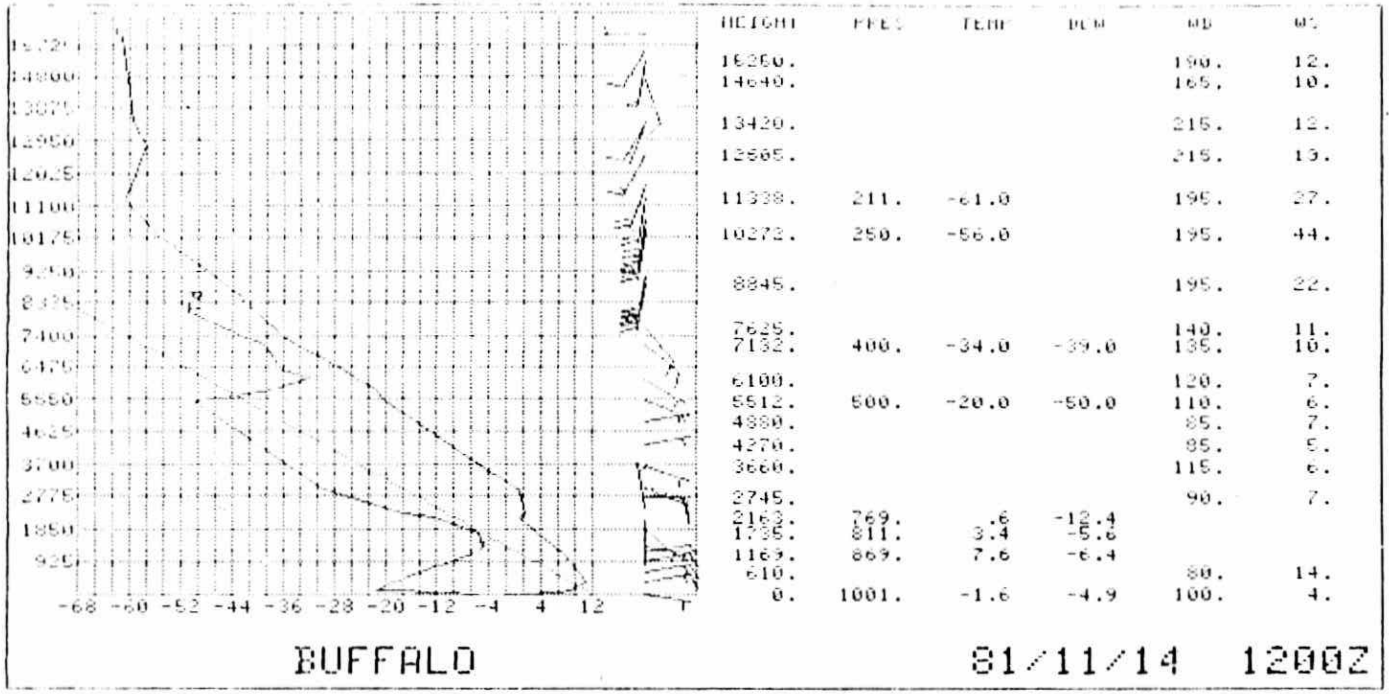


| HEIGHT | PRES | TEMP | DEW | WD | WS |
|---|---|---|---|---|---|
| 15860. | | | | 315. | 15. |
| 15250. | | | | 310. | 10. |
| 14640. | | | | 310. | 11. |
| 13466. | 150. | -60.8 | | 325. | 4. |
| 12726. | 169. | -61.4 | | | |
| 12299. | 181. | -58.4 | | | |
| 11686. | 200. | -62.6 | | 100. | 3. |
| 10877. | 228. | -61.8 | | 75. | 11. |
| 10296. | 250. | -57.4 | | 120. | 15. |
| 9116. | 300. | -48.6 | | 116. | 22. |
| 8540. | | | | 120. | 16. |
| 8100. | 349. | -38.8 | -47.8 | | |
| 7625. | | | | 75. | 12. |
| 7156. | 400. | -31.2 | -37.2 | 50. | 10. |
| 6100. | | | | 350. | 10. |
| 5526. | 500. | -16.0 | -46.0 | 5. | 11. |
| 4880. | | | | 5. | 11. |
| 4270. | | | | 15. | 15. |
| 3660. | | | | 10. | 13. |
| 2913. | 700. | .8 | -29.2 | 355. | 13. |
| 2348. | 751. | -.4 | -10.4 | | |
| 1830. | | | | 5. | 13. |
| 1220. | | | | 10. | 12. |
| 610. | | | | 300. | 4. |
| 0. | 1003. | -3.2 | -6.0 | 140. | 6. |

BUFFALO 81/11/13 1200Z

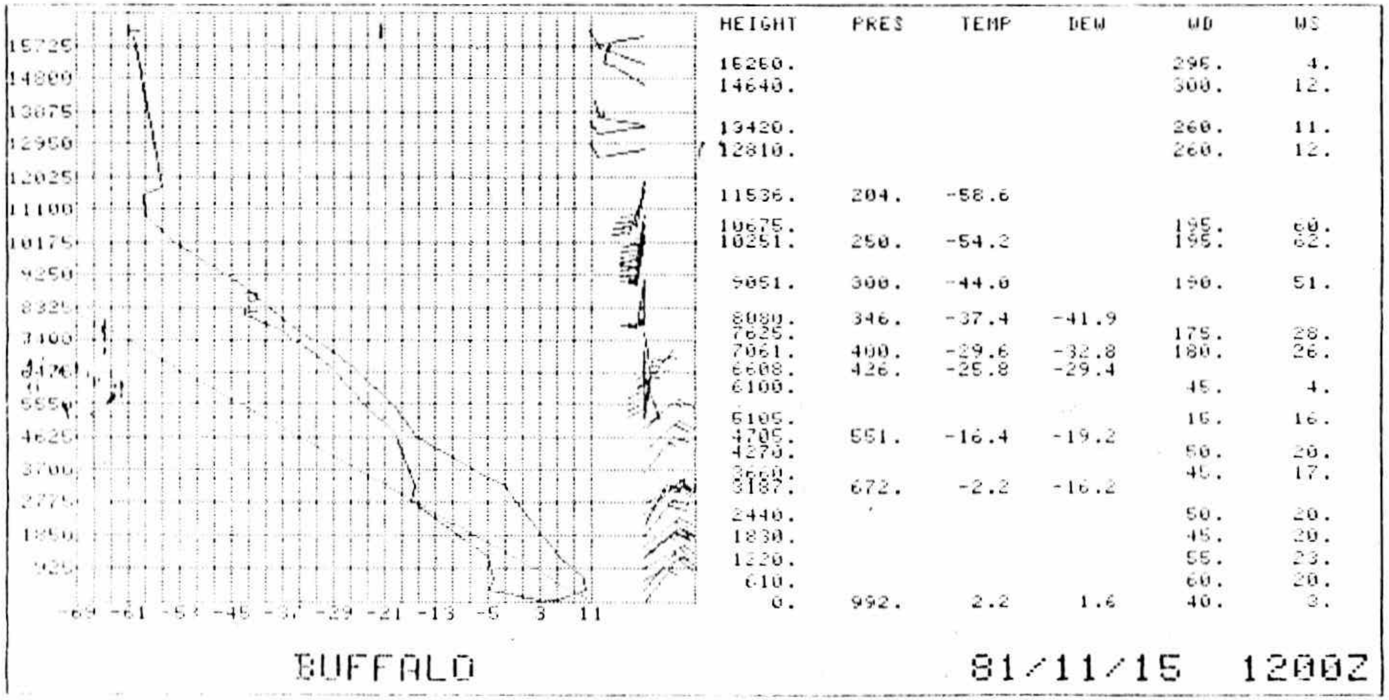
Figure 14 (con'd)

Figure 14 (Cont'd)



| HEIGHT | PRES | TEMP | DEW | WD | WS |
|---|---|---|---|---|---|
| 16260. | | | | 190. | 12. |
| 14640. | | | | 165. | 10. |
| 13420. | | | | 215. | 12. |
| 12665. | | | | 215. | 13. |
| 11338. | 211. | -61.0 | | 195. | 27. |
| 10272. | 250. | -56.0 | | 195. | 44. |
| 8845. | | | | 195. | 22. |
| 7625. | | | | 140. | 11. |
| 7132. | 400. | -34.0 | -39.0 | 135. | 10. |
| 6100. | | | | 120. | 7. |
| 5512. | 500. | -20.0 | -50.0 | 110. | 6. |
| 4880. | | | | 85. | 7. |
| 4270. | | | | 85. | 5. |
| 3660. | | | | 115. | 6. |
| 2745. | | | | 90. | 7. |
| 2163. | 769. | .6 | -12.4 | | |
| 1735. | 811. | 3.4 | -5.6 | | |
| 1169. | 869. | 7.6 | -6.4 | | |
| 610. | | | | 80. | 14. |
| 0. | 1001. | -1.6 | -4.9 | 100. | 4. |

BUFFALO 81/11/14 1200Z



| HEIGHT | PRES | TEMP | DEW | WD | WS |
|---|---|---|---|---|---|
| 16260. | | | | 295. | 4. |
| 14640. | | | | 300. | 12. |
| 13420. | | | | 260. | 11. |
| 12810. | | | | 260. | 12. |
| 11536. | 204. | -58.6 | | | |
| 10675. | | | | 195. | 60. |
| 10251. | 250. | -54.2 | | 195. | 62. |
| 9051. | 300. | -44.0 | | 190. | 51. |
| 8080. | 346. | -37.4 | -41.9 | | |
| 7625. | | | | 175. | 28. |
| 7061. | 400. | -29.6 | -32.8 | 180. | 26. |
| 6608. | 426. | -25.8 | -29.4 | | |
| 6100. | | | | 45. | 4. |
| 5105. | | | | 16. | 16. |
| 4705. | 551. | -16.4 | -19.2 | | |
| 4270. | | | | 50. | 20. |
| 3660. | | | | 45. | 17. |
| 3187. | 672. | -2.2 | -16.2 | | |
| 2440. | | | | 50. | 20. |
| 1830. | | | | 45. | 20. |
| 1220. | | | | 55. | 23. |
| 610. | | | | 60. | 20. |
| 0. | 992. | 2.2 | 1.6 | 40. | 3. |

BUFFALO 81/11/15 1200Z

# TABLES

1 TO 3

Table 1: Hi-Vol Data During API Episode (November 13-15, 1981)

| Station No. (Survey) | Station Address | Nov. 12/81 | | Nov. 13/81 | | Nov. 14/81 | | Nov. 15/81 | |
|---|---|---|---|---|---|---|---|---|---|
| | | TSP | Lead | TSP | Lead | TSP | Lead | TSP | Lead |
| 31104 (API) | 26 Breadalbane, Toronto | 40 | 0.2 | 125 | 2.1 | 113 | 2.3 | 44 | 0.7 |
| 31058 (Can. Metals) | Mosley/Leslie, Toronto | 77 | 0.7 | 198 | 4.7 | 139 | 4.0 | 70 | 1.2 |
| 31064 (Can. Metals) | 17 Berkshire, Toronto | 55 | 1.5 | - | - | 141 | 4.0 | 66 | 1.3 |
| 31065 (Can. Metals) | 633 Eastern, Toronto | 62 | 1.2 | 142 | 2.7 | 99 | 2.7 | 58 | 1.2 |
| 31082 (Can. Metals) | 138 Hamilton, Toronto | 54 | 1.2 | 184 | 5.3 | 129 | 4.6 | 64 | 1.8 |
| 31084 (Can. Metals) | 65 Saulter, Toronto | 77 | 0.4 | 154 | 2.8 | 115 | 3.3 | 70 | 1.4 |
| 31018 (Tor. Refiners) | Bathurst/Niagara, Toronto | 132 | 0.8 | 235 | 2.6 | 239 | 3.6 | 134 | 1.4 |
| 31085 (Tor. Refiners) | Tecumseh/Niagara, Toronto | 56 | 2.3 | 109 | 2.1 | 155 | 3.6 | 57 | 1.1 |
| 31079 (Prestolite) | Dufferin Street, Toronto | 43 | 0.5 | 42 | 0.6 | 157 | 4.6 | 68 | 1.6 |
| 35037 (Arrowhead Metals) | Lakeshore, Etobicoke | 73 | 0.9 | 133 | 2.1 | 129 | 3.5 | 45 | - |
| | Average | 67 | 1.0 | 147 | 2.8 | 141 | 3.6 | 68 | 1.3 |

Note: TSP = Total suspended particulates

Table 2: Dichotomous Data During Air Pollution Episode - Nov. 13-15, 1982
26 Breadalbane Street, Toronto

| Date | Fine Particulate < 2.5 u (ug/m$^3$) | Coarse Particulates 2.5-15 u (ug/m$^3$) | Total Particulates (ug/m$^3$) | Total Suspended Particulate (Hi-Vol) (ug/m$^3$) | Dichotomous/ Hi-Vol Ratio |
|---|---|---|---|---|---|
| Nov. 12/81 | 5.8 | 11.5 | 17.3 | | |
| Nov. 13/81 | 31.3 | 36.5 | 67.8 | 125 | 0.54 |
| Nov. 14/81 7:38 | 48.8 | 29.0 | 77.8 | | |
| Nov. 14/81 16:22 | 44.8 | 28.5 | 73.3 | | |
| *Average Concentration (from Sept. '80 - July '81 Study at 67 College Street, Toronto) | 15.8 | 17.9 | 33.7 | 58 | 0.58 |

# TABLE 3

TRAFFIC AND PASSENGER VOLUMES CROSSING CORDONS AND SCREENLINES
QUARTERLY 6:30 A.M. TO 11:30 P.M. ON A TYPICAL WEEKDAY
1981 TRAFFIC DATA LISTING NUMBER - 4 -

| CORDON | BOUND | TIME ENDG | PRVTE AUTOS | TAXI CABS | TTC BUS | OTHR BUS | LIGHT TRUCK | MDIM TRCK | HEAVY TRUCK | TOTAL VEH.S | AUTO PASS. | CABS PASS | T T C PASS. | O-BUS PASS. | ST-CAR PASNGR | SUBWAY PASNGR | GO-TRN PASNGR | TOTAL PASSNGR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DOWNTOWN CORE | INBOUND | 645 | 794 | 40 | 6 | 8 | 121 | 5 | 47 | 1021 | 1044 | 61 | 42 | 52 | 516 | 1372 | 174 | 3261 |
| | | 700 | 1097 | 62 | 7 | 8 | 162 | 6 | 57 | 1399 | 1449 | 97 | 83 | 49 | 531 | 1400 | 240 | 3849 |
| | | 715 | 1396 | 68 | 11 | 22 | 207 | 14 | 63 | 1781 | 1864 | 99 | 99 | 91 | 650 | 2396 | 1373 | 6572 |
| | | 730 | 1823 | 66 | 12 | 13 | 195 | 14 | 84 | 2207 | 2442 | 96 | 153 | 73 | 991 | 3603 | 371 | 7729 |
| | | 745 | 2093 | 105 | 16 | 20 | 194 | 14 | 87 | 2529 | 2848 | 161 | 178 | 118 | 1077 | 4806 | 999 | 10187 |
| | | 800 | 2456 | 119 | 14 | 24 | 215 | 20 | 83 | 2931 | 3355 | 193 | 197 | 170 | 1186 | 7372 | 4238 | 16711 |
| | | 815 | 2797 | 126 | 15 | 21 | 176 | 11 | 112 | 3258 | 3824 | 223 | 307 | 197 | 1292 | 6542 | 6147 | 18532 |
| | | - 830 | 2980 | 156 | 16 | 24 | 210 | 14 | 127 | 3527 | 4106 | 261 | 397 | 181 | 1258 | 10139 | 1878 | 18220 |
| | | 845 | 3196 | 205 | 15 | 39 | 238 | 14 | 127 | 3834 | 4289 | 329 | 232 | 224 | 1667 | 7620 | 2162 | 16523 |
| | | 900 | 3123 | 227 | 16 | 18 | 253 | 8 | 121 | 3766 | 4045 | 371 | 414 | 214 | 1246 | 9546 | 2273 | 18109 |
| | | - 915 | 2839 | 222 | 15 | 25 | 283 | 19 | 160 | 3563 | 3555 | 359 | 283 | 147 | 1112 | 7042 | 681 | 13179 |
| | | 930 | 2364 | 254 | 15 | 15 | 266 | 23 | 149 | 3086 | 3030 | 409 | 178 | 52 | 508 | 3696 | | 7873 |
| | | 945 | 2140 | 236 | 10 | 29 | 295 | 21 | 161 | 2892 | 2659 | 327 | 105 | 223 | 419 | 3063 | 260 | 7056 |
| | | 1000 | 2158 | 268 | 7 | 25 | 325 | 12 | 187 | 2982 | 2817 | 418 | 66 | 286 | 450 | 2885 | | 6922 |
| | | 1015 | 1961 | 238 | 10 | 24 | 337 | 19 | 156 | 2745 | 2532 | 347 | 114 | 242 | 313 | 1368 | 307 | 5223 |
| | | 1030 | 1862 | 213 | 7 | 18 | 266 | 19 | 148 | 2533 | 2462 | 324 | 145 | 163 | 349 | 1107 | | 4550 |
| | | 1045 | 1812 | 192 | 12 | 25 | 297 | 24 | 170 | 2532 | 2357 | 288 | 117 | 372 | 420 | 1637 | 195 | 5386 |
| | | 1100 | 1865 | 215 | 7 | 30 | 299 | 21 | 152 | 2589 | 2465 | 334 | 147 | 368 | 377 | 1967 | | 5658 |
| | | 1115 | 1832 | 217 | 8 | 19 | 310 | 21 | 178 | 2585 | 2423 | 305 | 100 | 353 | 383 | 777 | 266 | 4607 |
| | | 1130 | 1937 | 232 | 7 | 18 | 307 | 20 | 170 | 2691 | 2642 | 325 | 114 | 220 | 321 | 1026 | | 4648 |
| | | 1145 | 2002 | 233 | 10 | 32 | 286 | 21 | 157 | 2741 | 2663 | 335 | 111 | 245 | 306 | 1235 | 163 | 5058 |
| | | 1200 | 2034 | 241 | 11 | 22 | 265 | 12 | 126 | 2711 | 2719 | 372 | 96 | 342 | 272 | 2266 | | 6067 |
| | | 1215 | 1948 | 233 | 10 | 18 | 275 | 14 | 153 | 2651 | 2657 | 350 | 158 | 270 | 287 | 1236 | 208 | 5166 |
| | | 1230 | 1790 | 257 | 7 | 19 | 233 | 26 | 133 | 2465 | 2493 | 356 | 117 | 278 | 332 | 1982 | | 5558 |
| | | 1245 | 1736 | 220 | 12 | 41 | 235 | 18 | 132 | 2394 | 2393 | 301 | 151 | 375 | 379 | 1234 | 149 | 4982 |
| | | 1300 | 1657 | 249 | 7 | 21 | 226 | 13 | 127 | 2300 | 2377 | 363 | 80 | 350 | 348 | 1278 | | 4796 |
| | | 1315 | 1823 | 234 | 7 | 19 | 290 | 9 | 141 | 2523 | 2717 | 356 | 77 | 185 | 516 | 2193 | 202 | 6246 |
| | | 1330 | 1764 | 242 | 9 | 18 | 280 | 25 | 155 | 2493 | 2597 | 392 | 139 | 87 | 383 | 1314 | | 4912 |
| | | 1345 | 2017 | 250 | 9 | 26 | 285 | 20 | 147 | 2754 | 2867 | 361 | 157 | 367 | 301 | 1466 | 112 | 5631 |
| | | 1400 | 1924 | 236 | 8 | 17 | 289 | 12 | 149 | 2635 | 2689 | 357 | 131 | 91 | 450 | 2153 | | 5871 |
| | | 1415 | 1906 | 216 | 7 | 33 | 309 | 8 | 159 | 2638 | 2647 | 333 | 118 | 360 | 360 | 973 | 114 | 4905 |
| | | 1430 | 1834 | 227 | 7 | 14 | 319 | 15 | 152 | 2568 | 2514 | 341 | 130 | 199 | 343 | 1788 | | 5315 |
| | | 1445 | 1904 | 234 | 10 | 29 | 305 | 15 | 127 | 2624 | 2629 | 351 | 158 | 360 | 475 | 1262 | 70 | 5305 |
| | | 1500 | 1847 | 233 | 8 | 14 | 272 | 14 | 139 | 2527 | 2509 | 359 | 134 | 103 | 314 | 1393 | | 4812 |
| | | 1515 | 1706 | 249 | 11 | 10 | 239 | 20 | 120 | 2355 | 2290 | 335 | 165 | 109 | 514 | 1473 | 91 | 4977 |
| | | 1530 | 1693 | 250 | 14 | 12 | 266 | 17 | 127 | 2379 | 2251 | 354 | 197 | 114 | 551 | 1929 | | 5396 |
| | | 1545 | 1763 | 225 | 16 | 19 | 254 | 19 | 101 | 2397 | 2376 | 304 | 229 | 326 | 633 | 1995 | 91 | 5954 |
| | | 1600 | 1852 | 255 | 18 | 12 | 223 | 17 | 66 | 2443 | 2518 | 380 | 340 | 182 | 723 | 2430 | | 6573 |
| | | 1615 | 1882 | 208 | 15 | 20 | 227 | 14 | 70 | 2436 | 2529 | 284 | 329 | 298 | 776 | 2725 | 103 | 7044 |
| | | 1630 | 1868 | 208 | 15 | 23 | 180 | 21 | 62 | 2377 | 2485 | 294 | 267 | 259 | 574 | 2520 | | 6399 |
| | | 1645 | 2179 | 225 | 14 | 27 | 197 | 20 | 58 | 2720 | 3014 | 344 | 322 | 607 | 804 | 3887 | 74 | 9052 |
| | | 1700 | 2130 | 256 | 17 | 31 | 162 | 9 | 56 | 2661 | 2968 | 374 | 251 | 617 | 956 | 3302 | 45 | 8513 |
| | | 1715 | 2175 | 274 | 7 | 25 | 154 | 5 | 48 | 2688 | 2990 | 360 | 204 | 533 | 794 | 2782 | 131 | 7794 |
| | | 1730 | 2209 | 296 | 10 | 22 | 131 | 5 | 45 | 2718 | 3114 | 401 | 194 | 324 | 1072 | 2555 | 30 | 7690 |
| | | 1745 | 1923 | 316 | 9 | 19 | 138 | 12 | 18 | 2435 | 2782 | 438 | 169 | 414 | 462 | 1526 | 121 | 5912 |
| | | 1800 | 1952 | 273 | 14 | 17 | 138 | 10 | 28 | 2432 | 2803 | 371 | 119 | 358 | 598 | 1194 | 38 | 5481 |
| | | 1815 | 1791 | 223 | 8 | 20 | 121 | 5 | 21 | 2189 | 2662 | 309 | 89 | 442 | 501 | 1103 | 179 | 5285 |
| | | 1830 | 1671 | 232 | 8 | 14 | 133 | 11 | 21 | 2090 | 2497 | 341 | 61 | 125 | 436 | 815 | | 4275 |

# Table 3 (Cont'd)

TRAFFIC AND PASSENGER VOLUMES CROSSING CORDONS AND SCREENLINES
QUARTERLY 6:30 A.M. TO 11:30 P.M. ON A TYPICAL WEEKDAY
1981 TRAFFIC DATA LISTING NUMBER - 4 -

| CORDON | BOUND | TIME ENDG | PRVTE AUTOS | TAXI CABS | TTC BUS | OTHR BUS | LIGHT TRUCK | MDIM TRCK | HEAVY TRUCK | TOTAL VEH.S | AUTO PASS. | CABS PASS | TTC PASS | O-BUS PASS. | ST-CAR PASNGR | SUBWAY PASNGR | GO-TRN PASNGR | TOTAL PASSNGR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DOWNTOWN CORE | INBOUND | 1845 | 1598 | 237 | 7 | 16 | 113 | 4 | 27 | 2002 | 2534 | 365 | 93 | 145 | 283 | 1209 | 41 | 4670 |
| | | 1900 | 1399 | 209 | 5 | 11 | 101 | 9 | 24 | 1758 | 2236 | 324 | 78 | 140 | 360 | 761 | 7 | 3906 |
| | | 1915 | 1280 | 251 | 6 | 13 | 94 | 5 | 13 | 1662 | 2171 | 357 | 52 | 193 | 240 | 603 | 90 | 3706 |
| | | 1930 | 1295 | 237 | 3 | 11 | 94 | 1 | 15 | 1656 | 2274 | 355 | 74 | 51 | 265 | 834 | | 3853 |
| | | 1945 | 1384 | 247 | 3 | 13 | 80 | 2 | 11 | 1740 | 2548 | 387 | 48 | 100 | 241 | 577 | 67 | 3968 |
| | | 2000 | 1304 | 231 | 4 | 8 | 87 | 1 | 6 | 1641 | 2285 | 369 | 37 | 24 | 197 | 446 | | 3358 |
| | | 2015 | 1119 | 210 | 3 | 10 | 69 | 1 | 10 | 1422 | 1895 | 294 | 37 | 82 | 191 | 424 | 52 | 2975 |
| | | 2030 | 958 | 234 | 2 | 9 | 65 | 1 | 13 | 1282 | 1661 | 330 | 4 | 144 | 140 | 171 | | 2450 |
| | | 2045 | 984 | 226 | 5 | 6 | 62 | 3 | 9 | 1295 | 1670 | 321 | 31 | 35 | 160 | 514 | 23 | 2754 |
| | | 2100 | 880 | 224 | 3 | 5 | 49 | 3 | 12 | 1176 | 1536 | 317 | 18 | 11 | 194 | 387 | | 2463 |
| | | 2115 | 845 | 195 | 3 | 9 | 55 | 2 | 5 | 1114 | 1487 | 248 | 18 | 87 | 211 | 378 | 33 | 2462 |
| | | 2130 | 852 | 220 | 2 | 11 | 50 | 4 | 9 | 1148 | 1465 | 328 | 15 | 86 | 123 | 250 | | 2267 |
| | | 2145 | 876 | 202 | 4 | 11 | 76 | 2 | 7 | 1178 | 1465 | 261 | 38 | 150 | 205 | 244 | 25 | 2388 |
| | | 2200 | 851 | 217 | 2 | 5 | 59 | 1 | 7 | 1142 | 1534 | 339 | 10 | 67 | 147 | 274 | | 2371 |
| | | 2215 | 887 | 232 | 3 | 5 | 48 | 2 | 4 | 1181 | 1594 | 337 | 23 | 10 | 99 | 188 | 76 | 2327 |
| | | 2230 | 807 | 224 | 3 | 6 | 58 | 2 | 6 | 1106 | 1463 | 302 | 28 | 67 | 208 | 258 | | 2326 |
| | | 2245 | 873 | 208 | 3 | 7 | 52 | | 10 | 1153 | 1532 | 305 | 29 | 113 | 138 | 192 | 41 | 2350 |
| | | 2300 | 802 | 216 | 2 | 2 | 46 | 6 | 10 | 1084 | 1388 | 321 | 29 | 4 | 132 | 188 | | 2062 |
| | | 2315 | 750 | 206 | 2 | 2 | 46 | 2 | 7 | 1015 | 1298 | 325 | 12 | 6 | 110 | 189 | 47 | 1987 |
| | | 2330 | 701 | 184 | 2 | 1 | 38 | 5 | 4 | 935 | 1238 | 289 | 17 | 3 | 83 | 226 | | 1856 |
| INBOUND | | | 115950 | 14666 | 591 | 1180 | 12730 | 782 | 5586 | $\boxed{151485}$ | 165232 | 21617 | 8855 | 13633 | 33253 | 139686 | 23987 | 406263 |

## Table 3 (Cont'd)

TRAFFIC AND PASSENGER VOLUMES CROSSING CORDONS AND SCREENLINES
QUARTERLY 6:30 A.M. TO 11:30 P.M. ON A TYPICAL WEEKDAY
1981 TRAFFIC DATA LISTING NUMBER - 4 -

| CORDON | BOUND | TIME ENDG | PRVTE AUTOS | TAXI CABS | TTC BUS | OTHR BUS | LIGHT TRUCK | MDIM TRCK | HEAVY TRUCK | TOTAL VEH.S | AUTO PASS. | CABS PASS | T T C PASS. | O-BUS PASS. | ST-CAR PASNGR | SUBWAY PASNGR | GO-TRN PASNGR | TOTAL PASSNGR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DOWNTOWN CORE | OUTBOUND | 645 | 438 | 32 | 7 | 5 | 83 | 2 | 33 | 600 | 561 | 47 | 57 | 23 | 241 | 500 | 56 | 1485 |
| | | 700 | 628 | 39 | 7 | 10 | 110 | 5 | 45 | 844 | 791 | 54 | 61 | 29 | 392 | 335 | 22 | 1684 |
| | | 715 | 831 | 63 | 11 | 14 | 117 | 3 | 65 | 1104 | 1047 | 86 | 114 | 46 | 500 | 475 | 53 | 2321 |
| | | 730 | 1107 | 68 | 11 | 14 | 170 | 8 | 50 | 1428 | 1395 | 92 | 83 | 40 | 583 | 553 | 56 | 2802 |
| | | 745 | 1284 | 103 | 11 | 18 | 142 | 14 | 63 | 1635 | 1626 | 148 | 105 | 126 | 970 | 728 | 70 | 3773 |
| | | 800 | 1560 | 117 | 18 | 20 | 153 | 10 | 71 | 1949 | 1942 | 165 | 187 | 59 | 893 | 1392 | | 4638 |
| | | 815 | 1607 | 144 | 15 | 23 | 161 | 13 | 92 | 2055 | 1962 | 198 | 140 | 99 | 779 | 1860 | 31 | 5069 |
| | | 830 | 1751 | 198 | 18 | 15 | 161 | 14 | 90 | 2247 | 2186 | 276 | 265 | 141 | 682 | 2259 | | 5809 |
| | | 845 | 1710 | 174 | 14 | 29 | 164 | 12 | 95 | 2198 | 2062 | 226 | 142 | 269 | 550 | 1704 | 50 | 5003 |
| | | 900 | 1669 | 189 | 17 | 23 | 180 | 10 | 87 | 2175 | 1984 | 266 | 152 | 194 | 591 | 1040 | | 4227 |
| | | 915 | 1563 | 229 | 18 | 34 | 215 | 14 | 115 | 2188 | 1847 | 327 | 64 | 339 | 493 | 585 | 31 | 3686 |
| | | 930 | 1413 | 220 | 13 | 26 | 194 | 19 | 106 | 1991 | 1738 | 312 | 167 | 240 | 262 | 679 | | 3398 |
| | | 945 | 1298 | 223 | 16 | 17 | 256 | 13 | 120 | 1943 | 1580 | 323 | 158 | 165 | 406 | 458 | 46 | 3136 |
| | | 1000 | 1353 | 205 | 11 | 28 | 242 | 27 | 142 | 2008 | 1671 | 291 | 157 | 348 | 216 | 515 | | 3198 |
| | | 1015 | 1319 | 223 | 10 | 30 | 246 | 20 | 125 | 1973 | 1680 | 317 | 140 | 494 | 317 | 402 | 54 | 3404 |
| | | 1030 | 1362 | 215 | 8 | 20 | 288 | 16 | 139 | 2048 | 1752 | 300 | 121 | 156 | 320 | 734 | | 3383 |
| | | 1045 | 1456 | 196 | 9 | 17 | 276 | 15 | 166 | 2135 | 1914 | 273 | 99 | 131 | 210 | 534 | 84 | 3245 |
| | | 1100 | 1580 | 208 | 11 | 20 | 272 | 24 | 136 | 2251 | 2059 | 294 | 137 | 231 | 314 | 730 | | 3765 |
| | | 1115 | 1775 | 238 | 9 | 15 | 297 | 19 | 170 | 2523 | 2321 | 349 | 117 | 136 | 208 | 640 | 24 | 3795 |
| | | 1130 | 1696 | 222 | 10 | 22 | 313 | 21 | 180 | 2464 | 2251 | 314 | 183 | 277 | 292 | 361 | | 3678 |
| | | 1145 | 1773 | 219 | 8 | 17 | 322 | 17 | 168 | 2524 | 2333 | 318 | 134 | 70 | 341 | 1192 | 93 | 4481 |
| | | 1200 | 1895 | 263 | 9 | 24 | 276 | 25 | 148 | 2640 | 2502 | 435 | 137 | 434 | 264 | 1075 | | 4847 |
| | | 1215 | 1886 | 244 | 8 | 22 | 233 | 19 | 144 | 2556 | 2584 | 391 | 106 | 304 | 432 | 1064 | 44 | 4925 |
| | | 1230 | 1780 | 282 | 12 | 15 | 269 | 21 | 124 | 2503 | 2474 | 459 | 170 | 179 | 328 | 1151 | | 4761 |
| | | 1245 | 1839 | 214 | 10 | 23 | 247 | 18 | 99 | 2450 | 2500 | 331 | 129 | 105 | 346 | 1088 | 113 | 4612 |
| | | 1300 | 1744 | 217 | 9 | 25 | 244 | 14 | 131 | 2384 | 2413 | 334 | 165 | 240 | 499 | 738 | | 4389 |
| | | 1315 | 1650 | 216 | 10 | 25 | 259 | 12 | 115 | 2287 | 2257 | 335 | 169 | 262 | 452 | 1788 | 79 | 5342 |
| | | 1330 | 1735 | 229 | 10 | 17 | 248 | 21 | 121 | 2381 | 2432 | 365 | 201 | 87 | 464 | 781 | | 4330 |
| | | 1345 | 1897 | 230 | 11 | 22 | 253 | 13 | 132 | 2558 | 2644 | 345 | 198 | 376 | 347 | 1638 | 157 | 5705 |
| | | 1400 | 1894 | 236 | 10 | 17 | 286 | 13 | 122 | 2578 | 2608 | 384 | 126 | 158 | 428 | 1278 | | 4982 |
| | | 1415 | 1870 | 237 | 11 | 22 | 294 | 11 | 142 | 2587 | 2622 | 385 | 224 | 213 | 442 | 1520 | 133 | 5539 |
| | | 1430 | 2073 | 225 | 9 | 24 | 277 | 10 | 115 | 2733 | 2817 | 343 | 181 | 323 | 465 | 1408 | | 5537 |
| | | 1445 | 1994 | 235 | 10 | 26 | 311 | 13 | 128 | 2717 | 2698 | 362 | 149 | 193 | 440 | 917 | 272 | 5031 |
| | | 1500 | 2031 | 222 | 8 | 18 | 283 | 16 | 144 | 2722 | 2811 | 364 | 96 | 154 | 482 | 2888 | | 6795 |
| | | 1515 | 1858 | 236 | 12 | 7 | 275 | 16 | 104 | 2508 | 2499 | 340 | 190 | 39 | 569 | 1937 | 214 | 5788 |
| | | 1530 | 2078 | 251 | 11 | 18 | 256 | 14 | 111 | 2739 | 2791 | 353 | 196 | 339 | 546 | 2320 | | 6545 |
| | | 1545 | 2026 | 237 | 16 | 20 | 302 | 17 | 97 | 2715 | 2757 | 353 | 202 | 404 | 825 | 2616 | 511 | 7668 |
| | | 1600 | 2091 | 262 | 17 | 19 | 259 | 19 | 84 | 2751 | 2809 | 399 | 196 | 332 | 643 | 3727 | 452 | 8558 |
| | | 1615 | 2399 | 211 | 12 | 28 | 270 | 15 | 73 | 3008 | 3276 | 342 | 202 | 425 | 907 | 5678 | 1726 | 12556 |
| | | 1630 | 2324 | 230 | 21 | 20 | 210 | 21 | 50 | 2876 | 3255 | 363 | 327 | 360 | 1262 | 4925 | | 10492 |
| | | 1645 | 2743 | 205 | 15 | 19 | 211 | 14 | 61 | 3268 | 4053 | 320 | 284 | 487 | 1130 | 6839 | 3459 | 16572 |
| | | - 1700 | 2793 | 255 | 16 | 30 | 218 | 6 | 52 | 3370 | 4108 | 421 | 377 | 549 | 1501 | 8350 | 1997 | 17303 |
| | | 1715 | 2807 | 217 | 10 | 23 | 180 | 7 | 49 | 3293 | 4121 | 343 | 302 | 494 | 977 | 10231 | 3450 | 19918 |
| | | 1730 | 3153 | 283 | 11 | 20 | 178 | 3 | 42 | 3690 | 4571 | 461 | 221 | 273 | 1845 | 6391 | 4259 | 18021 |
| | | - 1745 | 2782 | 277 | 19 | 17 | 176 | 8 | 31 | 3310 | 4042 | 446 | 260 | 235 | 1354 | 7575 | 1804 | 15716 |
| | | 1800 | 2550 | 293 | 9 | 14 | 148 | 5 | 29 | 3048 | 3660 | 467 | 90 | 216 | 1116 | 4114 | 325 | 9988 |
| | | 1815 | 2416 | 303 | 8 | 17 | 133 | 8 | 30 | 2915 | 3570 | 522 | 123 | 262 | 938 | 3257 | 1059 | 9731 |
| | | 1830 | 2049 | 299 | 11 | 19 | 133 | 9 | 22 | 2542 | 2986 | 512 | 171 | 394 | 533 | 2642 | 326 | 7564 |

## Table 3 (Cont'd)

TRAFFIC AND PASSENGER VOLUMES CROSSING CORDONS AND SCREENLINES
QUARTERLY 6:30 A.M. TO 11:30 P.M. ON A TYPICAL WEEKDAY
1981 TRAFFIC DATA LISTING NUMBER - 4 -

| C O R D O N | BOUND | TIME ENDG | PRVTE AUTOS | TAXI CABS | TTC BUS | OTHR BUS | LIGHT TRUCK | MDIM TRCK | HEAVY TRUCK | TOTAL VEH.S | AUTO PASS. | CABS PASS | T T C PASS. | O-BUS PASS. | ST-CAR PASNGR | SUBWAY PASNGR | GO-TRN PASNGR | TOTAL PASSNGR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DOWNTOWN CORE | OUTBOUND | 1845 | 1778 | 263 | 4 | 15 | 113 | 10 | 23 | 2206 | 2719 | 464 | 105 | 368 | 654 | 1594 | 400 | 6304 |
| | | 1900 | 1529 | 226 | 8 | 17 | 85 | 8 | 19 | 1892 | 2387 | 433 | 222 | 112 | 527 | 1312 | | 4993 |
| | | 1915 | 1508 | 225 | 7 | 17 | 101 | 3 | 15 | 1876 | 2475 | 408 | 83 | 202 | 209 | 1414 | 84 | 4875 |
| | | 1930 | 1426 | 238 | 3 | 10 | 100 | | 8 | 1785 | 2380 | 403 | 53 | 60 | 610 | 1150 | | 4656 |
| | | 1945 | 1370 | 215 | 3 | 14 | 72 | 4 | 18 | 1696 | 2354 | 364 | 44 | 257 | 309 | 1404 | 392 | 5124 |
| | | 2000 | 1456 | 260 | 2 | 12 | 79 | 3 | 17 | 1829 | 2477 | 459 | 14 | 124 | 314 | 957 | | 4345 |
| | | 2015 | 1265 | 229 | 4 | 9 | 94 | | 11 | 1612 | 2099 | 381 | 54 | 78 | 307 | 878 | 228 | 4025 |
| | | 2030 | 1233 | 232 | 4 | 4 | 78 | | 9 | 1560 | 2047 | 389 | 43 | 11 | 277 | 828 | | 3595 |
| | | 2045 | 1141 | 218 | 3 | 9 | 84 | | 9 | 1464 | 1955 | 390 | 29 | 72 | 265 | 780 | 284 | 3775 |
| | | 2100 | 1097 | 199 | 4 | 8 | 71 | | 14 | 1393 | 1877 | 315 | 31 | 15 | 269 | 748 | | 3255 |
| | | 2115 | 1235 | 212 | 2 | 6 | 75 | 2 | 10 | 1542 | 2052 | 365 | 26 | 66 | 233 | 979 | 157 | 3878 |
| | | 2130 | 1161 | 204 | 4 | 7 | 59 | 1 | 10 | 1446 | 1961 | 330 | 27 | 59 | 272 | 1181 | | 3830 |
| | | 2145 | 1089 | 219 | 3 | 10 | 74 | | 6 | 1401 | 1864 | 359 | 27 | 146 | 310 | 836 | 295 | 3837 |
| | | 2200 | 1063 | 242 | 3 | 7 | 59 | 2 | 4 | 1380 | 1900 | 395 | 18 | 56 | 240 | 519 | | 3128 |
| | | 2215 | 1321 | 227 | 4 | 8 | 61 | 2 | | 1623 | 2347 | 371 | 42 | 99 | 281 | 730 | 183 | 4053 |
| | | 2230 | 1112 | 241 | 2 | 10 | 66 | | 10 | 1441 | 2016 | 398 | 28 | 207 | 172 | 945 | | 3766 |
| | | 2245 | 1362 | 263 | 3 | 10 | 66 | 1 | 4 | 1709 | 2737 | 436 | 30 | 146 | 207 | 493 | 227 | 4276 |
| | | 2300 | 1210 | 257 | 4 | 6 | 62 | 1 | 8 | 1548 | 2370 | 440 | 34 | 89 | 243 | 1203 | | 4379 |
| | | 2315 | 990 | 211 | 2 | 2 | 52 | | 3 | 1260 | 1771 | 336 | 34 | 2 | 167 | 523 | 159 | 2992 |
| | | 2330 | 925 | 199 | 3 | 1 | 44 | 2 | 3 | 1177 | 1632 | 326 | 43 | 1 | 178 | 581 | | 2761 |
| OUTBOUND | | | 112801 | 14714 | 639 | 1150 | 12286 | 703 | 4959 | 147252 | 161982 | 23213 | 8962 | 13620 | 35139 | 124667 | 23459 | 391042 |
| TOTAL:IN- & OUT-BOUND | | | 228751 | 29380 | 1230 | 2330 | 25016 | 1485 | 10545 | 298737 | 327214 | 44830 | 17817 | 27253 | 68392 | 264353 | 47446 | 797305 |

# APPENDIX A

FACTS "About Ontario's Air Pollution Index", Publication Code AFS6

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FACTS

Ministry of the Environment
Ontario

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Minister

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# ABOUT ONTARIO'S AIR POLLUTION INDEX

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Air pollution being such a topical subject, it is desirable for the public to have a day-to-day knowledge of pollution levels and be readily able to compare these levels with those reached during "air pollution episodes". It is well known that such episodes in the past, in other parts of the world, have caused an increase in human sickness and mortality for people with respiratory problems. In Ontario, an Air Pollution Index (API) developed by the Air Resources Branch of the Ministry of the Environment, is used as a basis for action in an alert system to control or prevent an air pollution episode.

Epidemiological studies have shown a relationship between the severity of health effects and the degree of air pollution as measured by concentrations of suspended particulate matter and sulphur dioxide. Although extensive data was available for analyses of the concentrations of these pollutants during episodes, there was little information on the concentrations of other pollutants. It would seem desirable to have the Index as a function of concentration of all pollutants possible involved. The small amount of data available on other pollutants, however, was inadequate for determining their proper weights in an equation. Therefore, it was necessary at the time to consider only sulphur dioxide and suspended particulate matter in the design of Ontario's API.

Several other areas have developed air pollution indices, many of them designed for particular purposes. A report by G.C. Thom and W.R. Ott[1] describes and assesses most of the air pollution indices used in the United States and Canada.

Legislation in Ontario authorizes the Minister of the Environment to order any source not essential to public health or safety to curtail or shut down its operations when pollution levels are reached that could be injurious to health. To make possible the use of the Index as one of the bases of such control, it was designed to relate to pollution levels which could cause severe health effects like those during air pollution episodes.

The other basis of control is a meteorological forecast indicating the potential persistence of high pollution conditions.

## Sulphur Dioxide and Particulate Matter

To determine whether sulphur dioxide measurements could be used to indicate particulate matter, an attempt was made to correlate readings of $SO_2$ and COH readings. The correlation coefficient between the measured values was found to be quite low, especially during winter months when air pollution is an important factor in the development of an episode. Following are the correlation coefficients for each month:

$$r_{Nov} = 0.29;\ r_{Dec} = 0.14;$$

$$r_{Jan} = 0.06;\ r_{Feb} = 0.31$$

A similar, poor relationship was obtained for daily average sulphur dioxide concentrations and high-volume sampler measurements. The low correlation indicated that sulphur dioxide cannot be used to indicate particulate matter, and the Index must be a function of both sulphur dioxide and particulate matter concentrations.

Sulphur dioxide is measured directly by continuous analyzers and there is no difficulty in telemetering the levels of this pollutant from remote field stations to the Air Resources head office.

The suspended particulate matter, however, presents a problem. At present there is no practical method of measuring the concentrations of this pollutant directly for the periods of time desired and telemetering the measurements so that they are known on a real time basis.

At present, the techniques in Ontario involve the use of the Hemeon paper tape sampler and the high-volume sampler. The latter method provides concentrations in the desired units $ug/m^3$. The sampler draws a large volume of air (approximately 85 cubic metres per hour) through a filter paper for 24 hours. Measurements are obtained by weighing the filters in a laboratory before and after exposure. This data, however, cannot be telemetered on a real time basis.

The Hemeon paper tape sampler can be set to provide hourly readings which can be telemetered. Air is drawn through a portion of a filter paper tape. The tape is automatically advanced to a new position after each sampling period. The fundamental basis of evaluating the sample is optical. The transmittance of light through both filter and deposit is compared with the transmittance through a clean portion of the filter.

The difference in transmittance is converted into units of "coefficient of haze" (COH) per thousand linear feet of air passing through the filter. A COH unit is defined as that quality of light scattering solids on the filter which produces an optical density equivalent to .01 when measured by light transmission.

It is obvious that the COH measurements will not only depend on the amount of particulates in the air deposited on the tape, but also on the size, shape, and opacity of the particulates. Each location will thus have a different relationship between the COH value measured and the true concentration of the particulates.

With measurements of COH representing particulate concentrations in the equation, the Index will differ for each community. However, by the method of design, the significance of Index levels will be the same. With respect to the size of the particles obtained by the tape sampler, Dr. W.J. Ingram[2] determined a high correlation with COH values and the number of particles in the size range affecting the respiratory systems.

## The Design of An Index for Toronto

The relationship between the high-volume sampler data and COH values was determined for Toronto, as graphed in Figure 1. For comparison purposes, the relationship as determined for a New York station by Dr. Ingram is also shown.

For Toronto

$\text{HI VOL} = 240\ (\text{COH})^{.91}$ where HI VOL = suspended particulate matter concentrations in $ug/m^3$

COH = coefficient of haze/1,000 linear feet of air

The correlation coefficient for the above relationship is .70.

Data for sulphur dioxide and suspended particulate matter during air pollution episodes was obtained from summaries of epidemiological studies given in references #3, #4, #5 and #6. The data plotted in Figure 2 indicates the variability of episode. An analysis of the data revealed the following pairs of values could be used as the threshold to a severe episode at which the Air Pollution Index is set to equal 100:

1. Suspended particulates 600 $ug/m^3$ which for Toronto is equivalent to 2.74 COH and sulphur dioxide .13 ppm.

2. Suspended particulates 500 $ug/m^3$ equivalent to 2.24 COH and sulphur dioxide .25 ppm.

Setting the equation for the Air Pollution Index as a function of the 24-hour average concentrations of $SO_2$ and COH as follows:

$$API = A(COH) + B(SO_2) \tag{2}$$

The weighting to be given to each pollutant may be determined by setting API at the threshold level of an episode equal to 100 and substituting the foregoing given pairs of values for the 24-hour average concentrations of COH and $SO_2$. Equation (2) can be solved for A and B becoming:

$$API' = 30.5(COH) + 126.0(SO_2) \tag{3}$$

For a desirable scale the API was made to be an expotential function of API', that is, $API = C \left[API'\right]^D$

$$API = C \left[30.5(COH) + 126.0(SO_2)\right]^D \tag{4}$$

The levels of coefficient of haze and sulphur dioxide set by Ontario Regulations as objectives are 24-hour averages of COH at 1.0 and $SO_2$ at .10 ppm. Setting API = 32 at these levels provides a range of indices twice as great, that is, from 33 to 100, for control action to take place than for the range of acceptable levels, 0 to 32. Substituting API = 100 for levels of COH and $SO_2$ given above and API = 32 when COH = 1.0 and $SO_2$ = .10 equation (4) can be solved for C and D to give the equation for the Air Pollution Index for Toronto as follows:

$$API = .2 \left[30.5(COH) + 126.0(SO_2)\right]^{1.35}$$

Figure 2 shows the boundaries for API equal to 100 and 32 as well as for 50 and 75. Figure 3 illustrates the levels of the Index and describes effects of the pollution during a number of episodes. High pollution levels persisted during these episodes for more than one day. Setting the Index at 100 based on 24-hour averages, provides a margin of safety for action to take place before the severe effects of air pollution can take place.

The report by L.J. Brasser et al[5] noted that the number of days on which pollution levels remained high had a very marked effect on the severity of the episode. Temperatures were also a factor affecting the daily mortality increases. Most of the severe episodes with increased mortality occurred during the winter. For this reason, the relationship between high-volume samples and COH data was based on winter data only (November to March).

## An Air Pollution Alert System

An Air Pollution Index of less that 32 is considered acceptable. At these levels concentrations of sulphur dioxide and particulate matter should have little or no effect on human health. At the Advisory Level at which the Air Pollution Index = 32, and meteorological conditions are expected to remain adyerse for at least six more hours, owners of significant sources of pollution in the community in which this Index occurs may be advised to prepare to curtail operations.

The "First Alert" occurs when the Air Pollution Index reaches 50 and meteorological forecasts indicate high pollution potential conditions for at least six more hours. Owners of major sources may be ordered to curtail operations.

P.J. Lawther[7] reported that patients with chronic respiratory disease may experience accentuation of the symptoms during $SO_2$ levels of .21 ppm and particulate levels of 300 ug/$m^3$ corresponding to 1.3 COH. At this level the Air Pollution Index is equal to 58. This evidence as well as studies by B.W. Carnow et al[8] formed a basis for the proposed "First Alert" at 50, which incorporates a safety factor.

If the abatement action does not succeed to lower the levels of the Index, the "Second Alert" will be issued when the Index of 75 is reached and high pollution potential conditions are forecast for at least six more hours. Further curtailment of operations of sources producing emissions of pollution will be ordered.

At the "Air Pollution Episode Threshold Level" at which the Index reaches 100 and is forecast to continue for at least six more hours, owners of all sources not essential to public health or safety will be ordered to cease operations. At this level the conditions could have mild effects on healthy people and seriously endanger those with severe cardiac or respiratory disease.

The Index went into effect in Toronto on March 23, 1970, and was gradually expanded to other cities in the Province. It went into operation in Hamilton on June 15, 1970; Sudbury on January 16, 1971; Windsor on March 19, 1971; Niagara Falls on November 1, 1974; Coniston on February 18, 1975; New Sudbury on March 1, 1976; Sarnia on December 1, 1977; and St. Catharines on September 14, 1979. Welland was on the Index from 1974 to 1978.

## Grey Cup Smog 1962

In retrospect, the highest Air Pollution Index occurred in Toronto during November 30 to December 4, 1962, with the level reaching a peak reading of 155 during the evening of December 1, 1962, and 125 during the early morning hours of December 4, 1962. (See Figure 5.) Very light winds with temperatures ranging from 34 to 50 degrees and relative humidity of 10 per cent prevailed throughout most of the period.

While there is no recorded medical evidence of an increase in Toronto hospital admissions of people with respiratory illness during this period, a recent study by D. Levy, M. Gent and M.T. Newhouse[9] has related API levels in Hamilton, Ontario, to hospital admissions among adults and children with acute respiratory illness.

## Summary

The Air Pollution Index has been designed for use as the basis of an Air Pollution Alert System. Where the Index has been in operation, owners of pollution sources have co-operated in decreasing their emissions when advised that levels of the Index were near or approaching the 32 level. These actions have helped maintain lower levels of pollution. In all areas, permanent pollution abatement programs are in progress which should prevent future high Index levels.

The Index equation differs from place to place according to the relationship between particulate matter concentration, expressed in weight per unit volume of air and the measure of Coefficient of Haze. the design method followed, however, ensures that Index values have the same significance for each community.

The equation for the Index could be readily modified to relate directly to concentrations of suspended particulate matter, should an instrument become available capable of directly measuring and telemetering particulate concentrations on a continuous basis in the size range desired.

| | |
|---|---|
| First Printing: | April 1971 |
| Revised: | December 1972 |
| Third Printing: | September 1973 |
| Fourth Printing: | March 1976 |
| Fifth Printing: | June 1978 |
| Revised: | January 1980 |
| Seventh Printing: | November 1981 |

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2. Ingram W.J., Smoke Curve Calibration Report, Research Division, New York University, March 1969.

3. Air Quality Criteria for Particulate Matter, U.S. Department of Health, Education and Welfare, Public Health Service, January 1969.

4. Air Quality Criteria for Sulphur Oxides, U.S. Department of Health, Education and Welfare, Public Health Service, January 1969.

5. Brasser L.J., Joosting P.E., and Von Zuilen D., Sulphur Dioxide, To What Level Is It Acceptable? Research Institute for Public Health Engineering, Delft, Netherlands, Report G-300, July 1967.

6. Stern A.C., Air Pollution, Vol. 1, Academic Press 1968.

7. Lawther P.J., Climate, Air Pollution and Chronic Bronchitis, Proc. Roy, Soc. Med. 51, pg. 262-264, 1958.

8. Carnow B.W. et al, The Chicago Air Pollution Study: Acute Illness and $SO_2$ Levels in Patients with Chronic Bronchopulmonary Disease, A.P.C.A. Meeting Paper 68-39.

9. Levy D., Gent M., and Newhouse M.T., Relationship between Acute Respiratory Illness and Air Pollution Levels in an Industrial City. American Review of Respiratory Disease. Vol. 116, pg. 167-173, 1977.

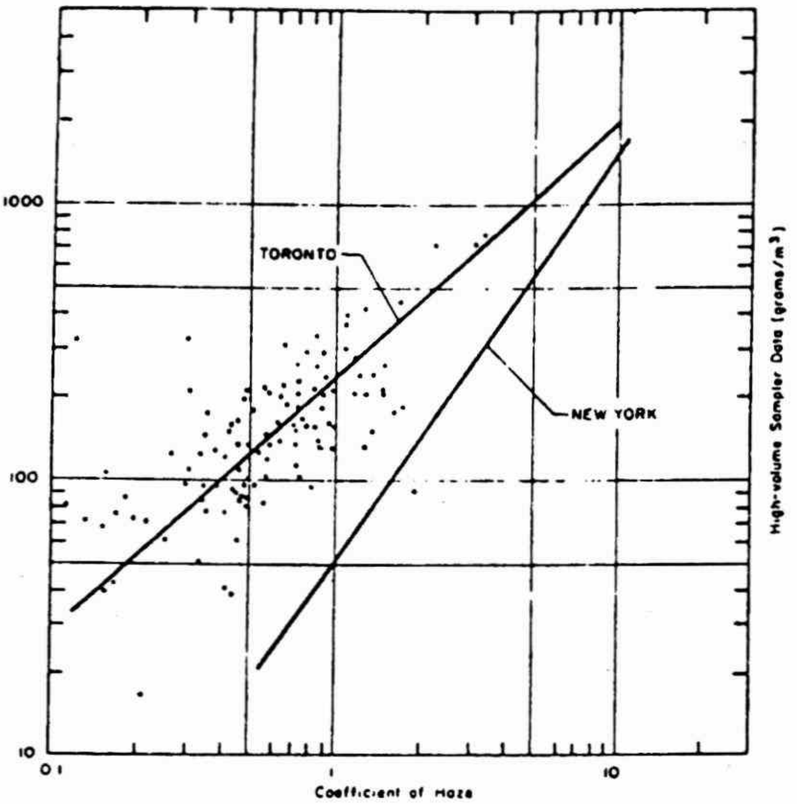


FIGURE 1: Relationship between the coefficient of Haze and high-volume sampler data for Toronto and New York

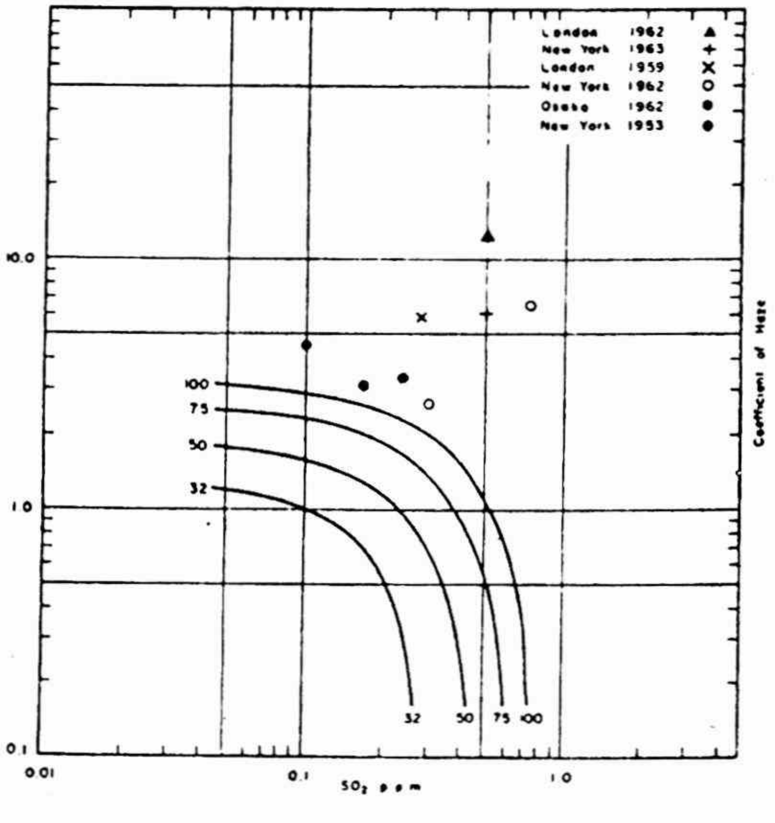


FIGURE 2: Air Pollution Index boundaries for values of 32, 50, 75 and 100 with episode levels plotted.

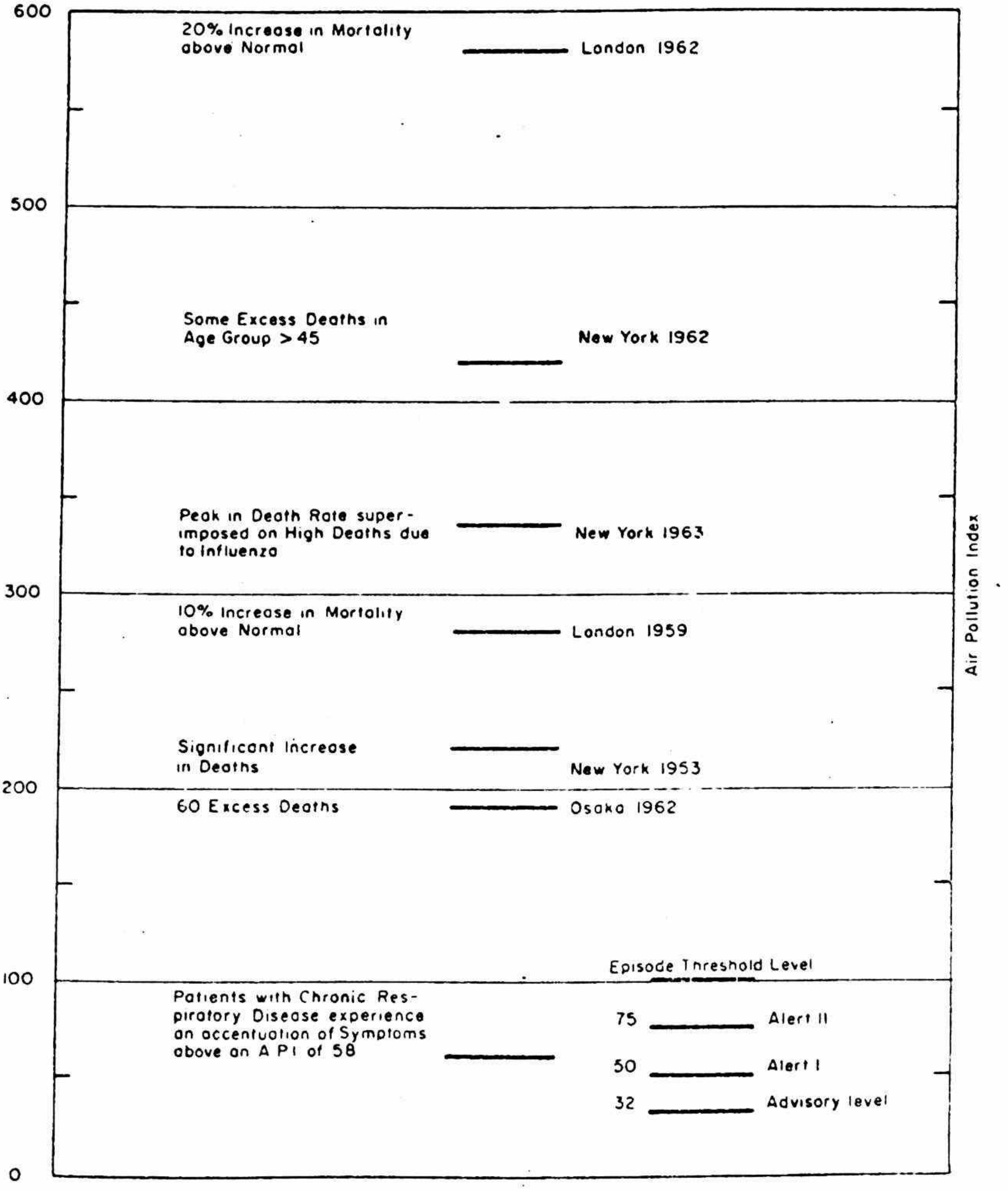


FIGURE 3: Levels of the Air Pollution Index during episodes and Ontario Alert System.

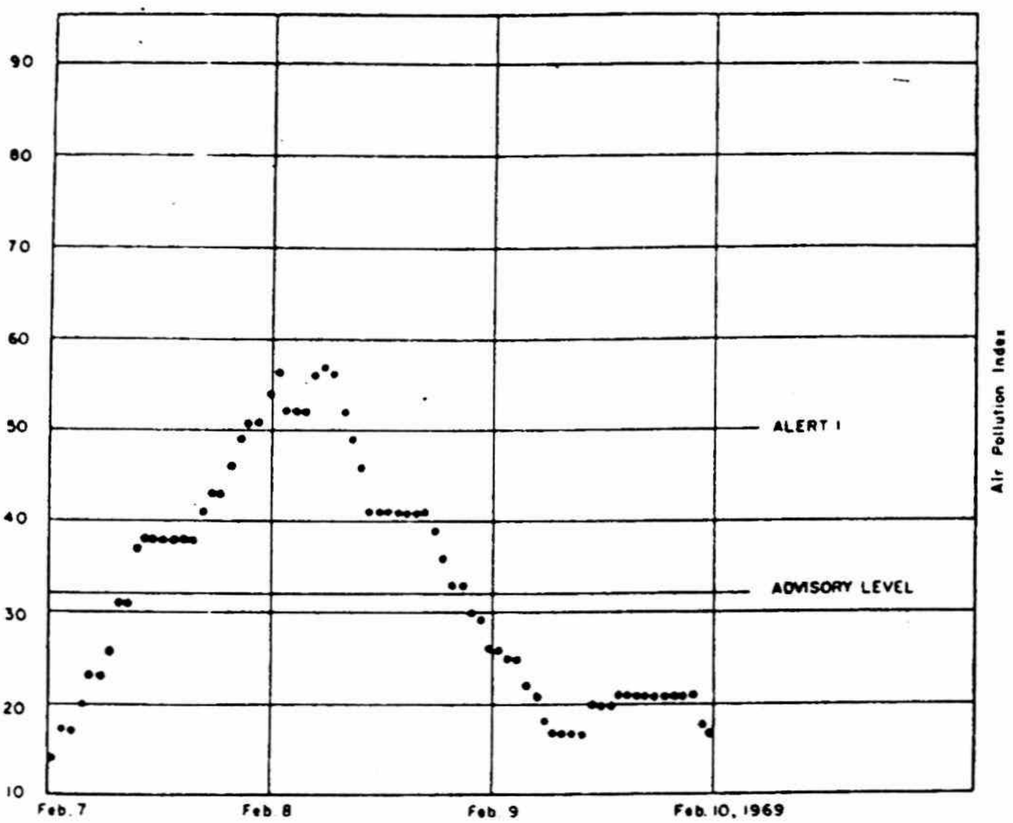


FIGURE 4: Index for period of highest pollution levels in Toronto during 1969.

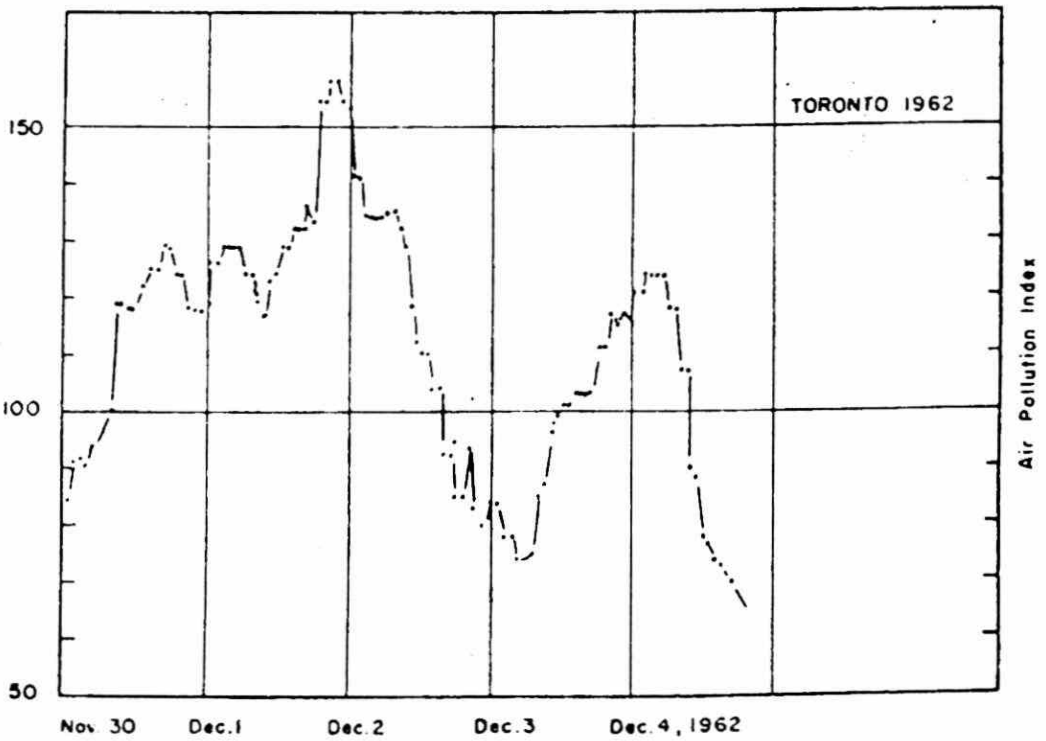
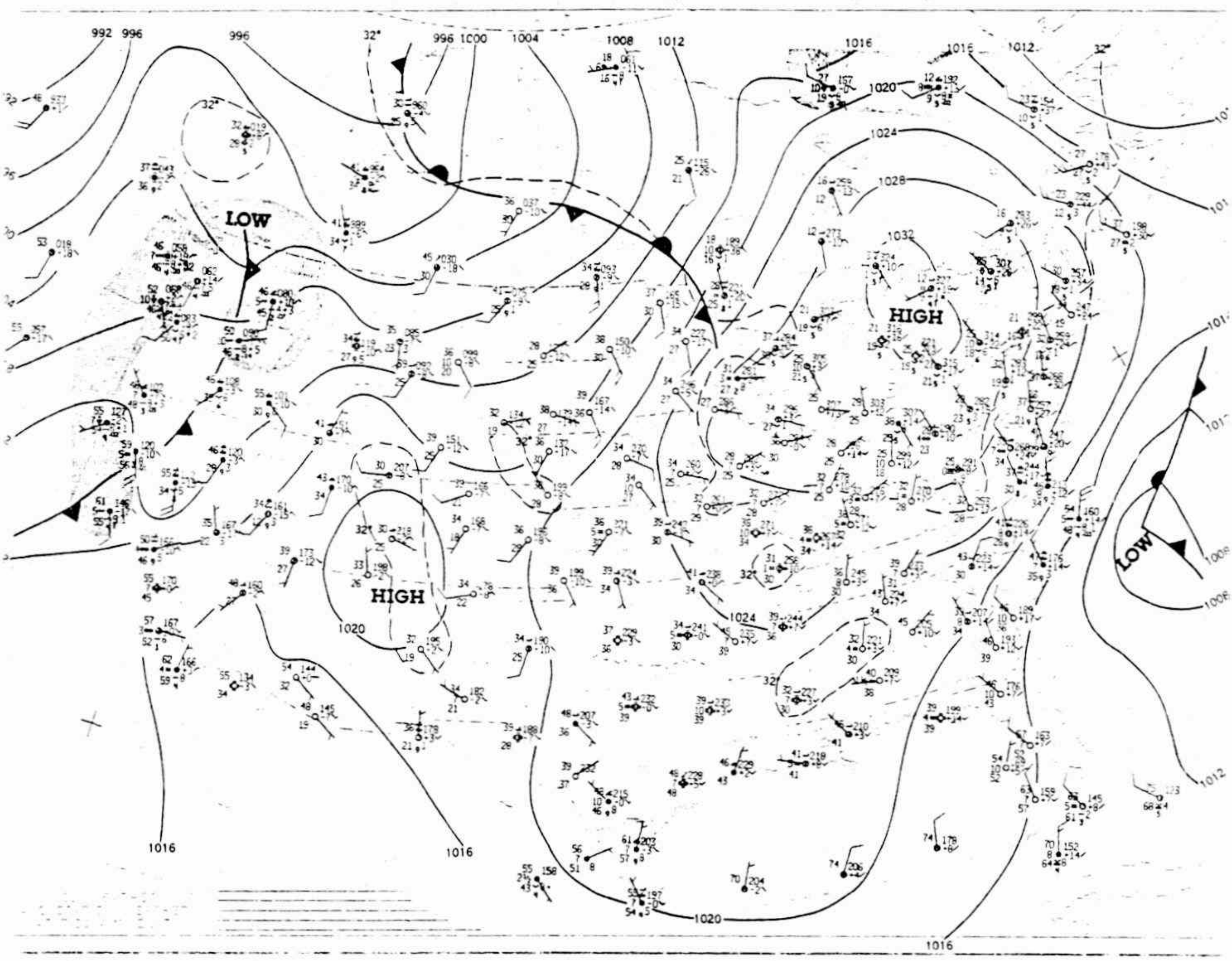


FIGURE 5: Air Pollution Index for period of highest pollution levels in Toronto.

# APPENDIX B

## Surface Weather Maps: November 12 - 15, 1981

U.S. Department of Commerce
National Oceanic And Atmospheric Administration
Environmental Data and Information Service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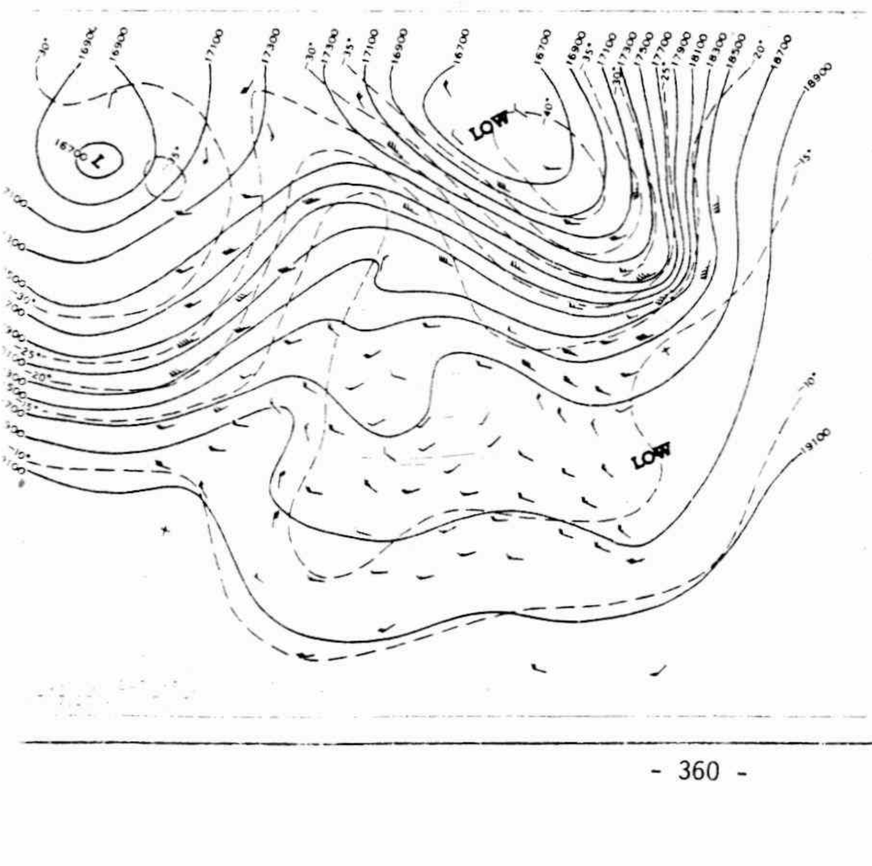
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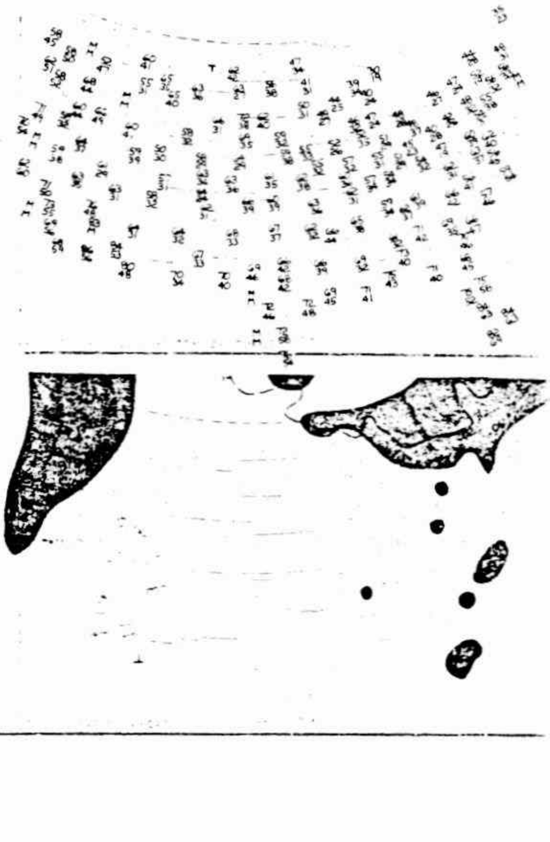

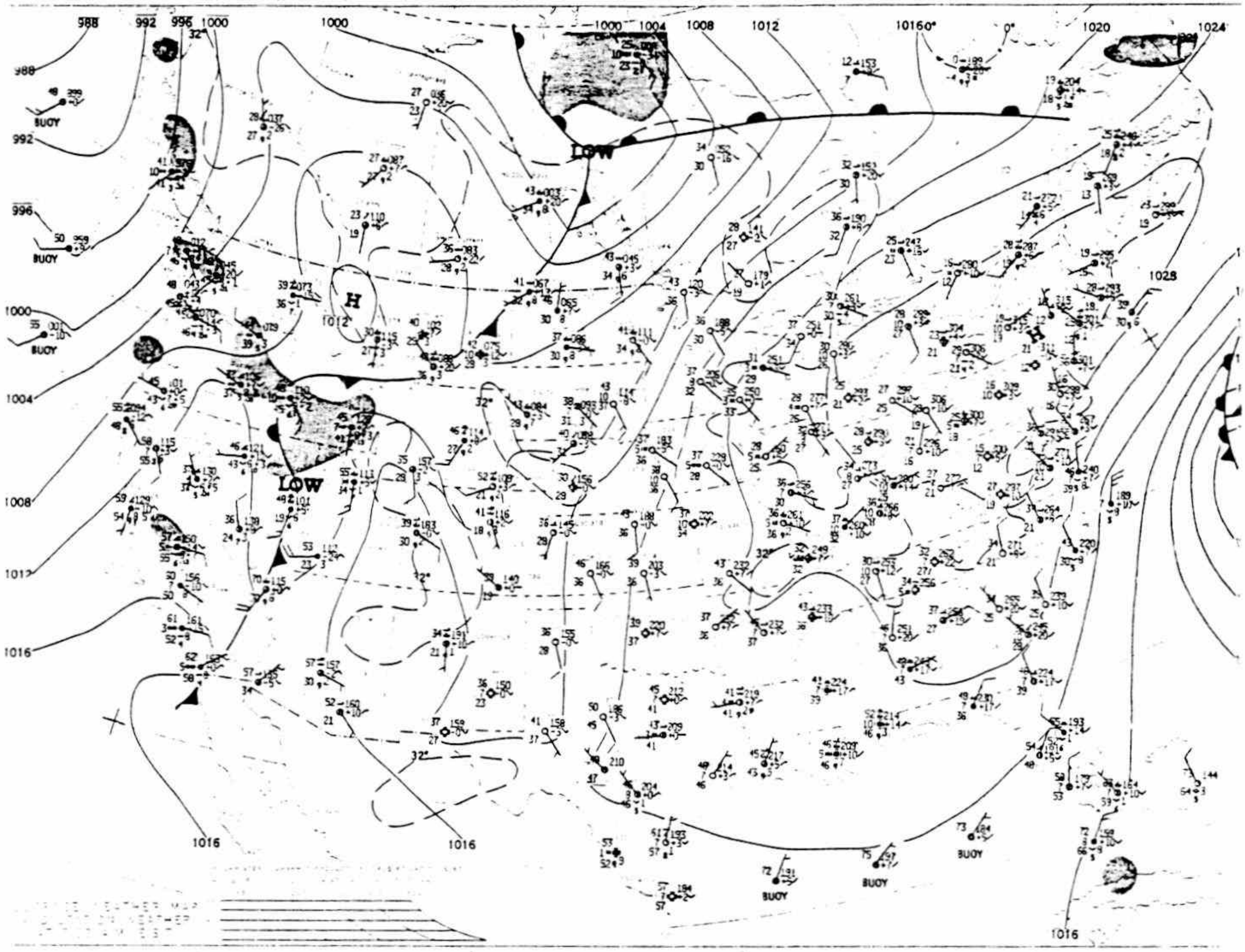
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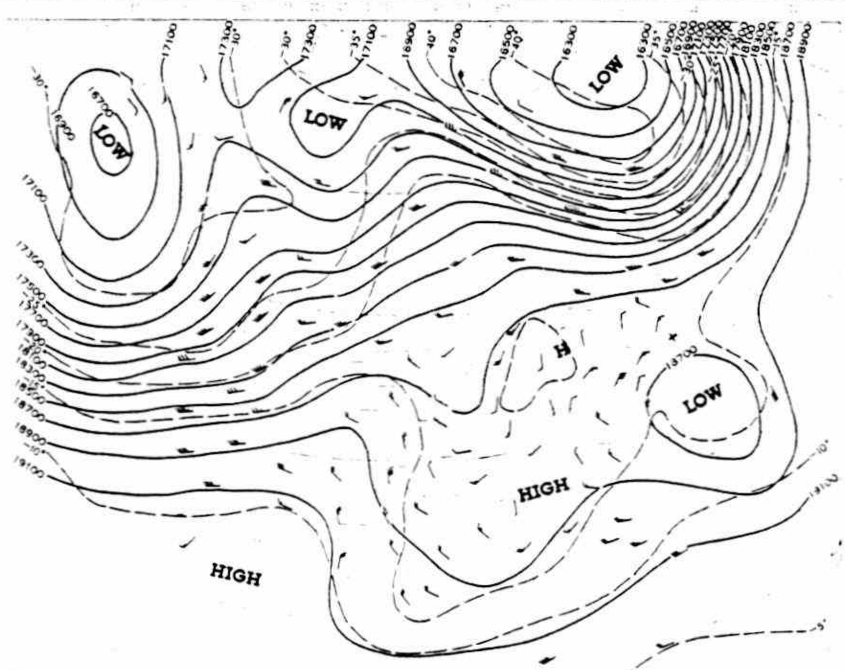
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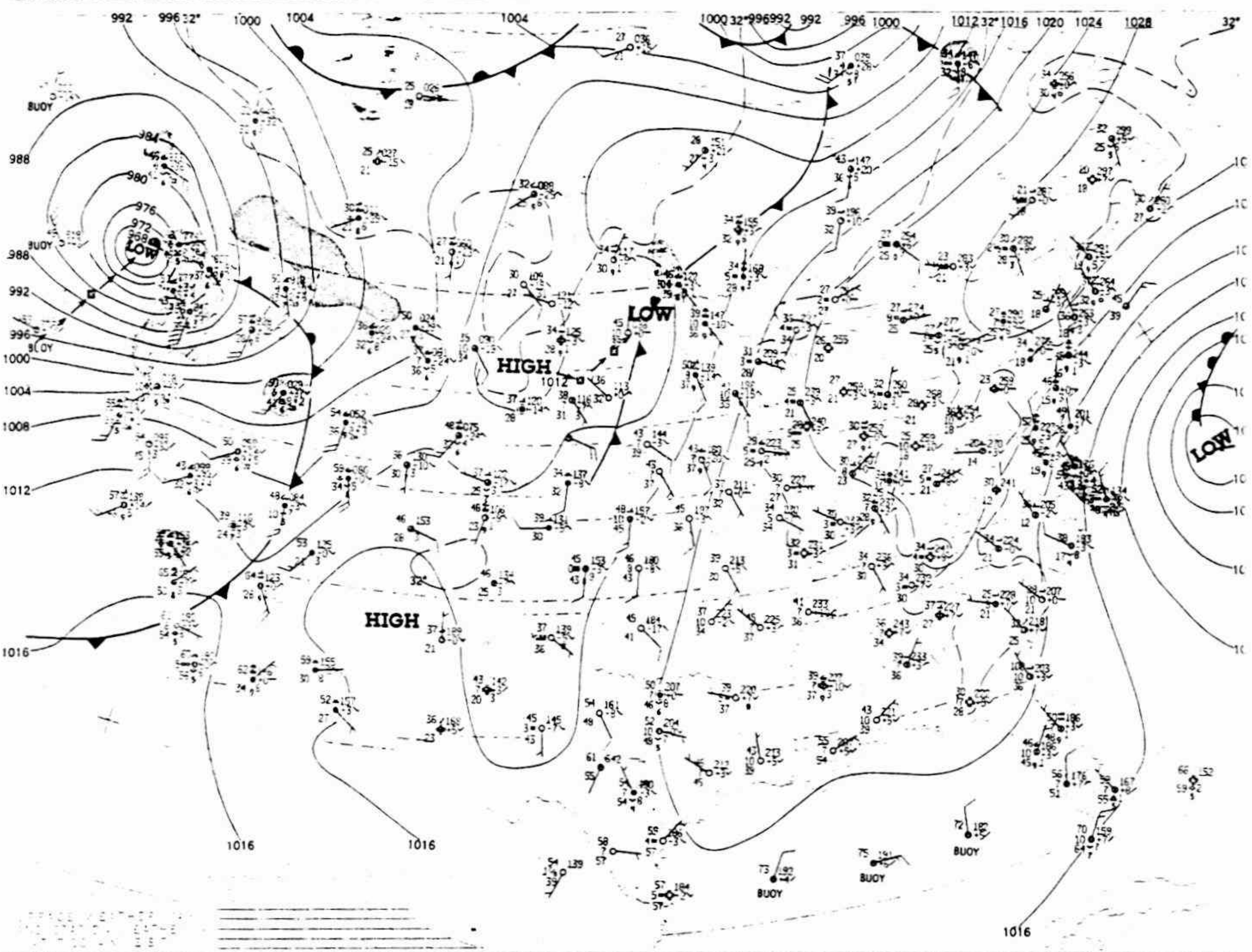

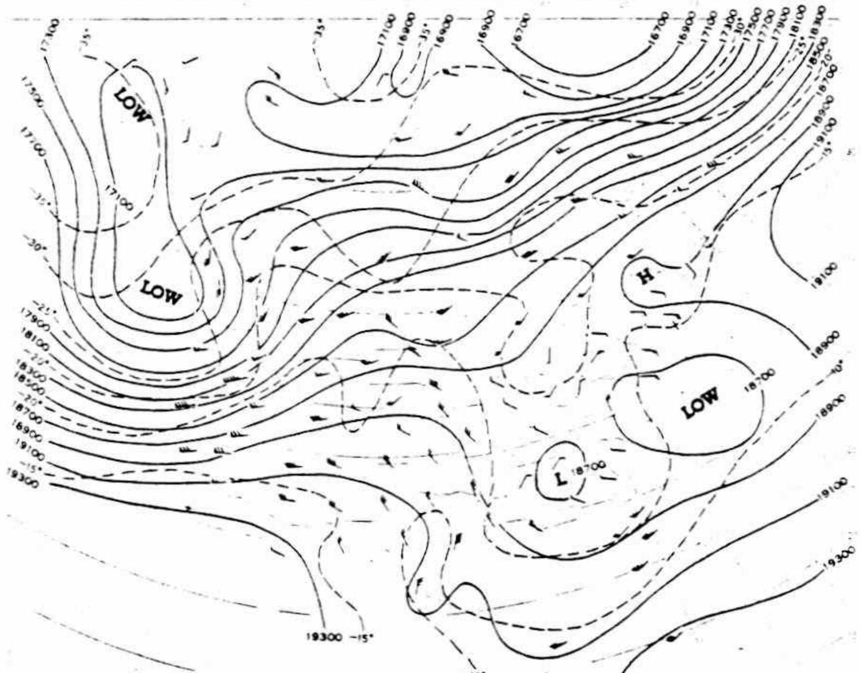

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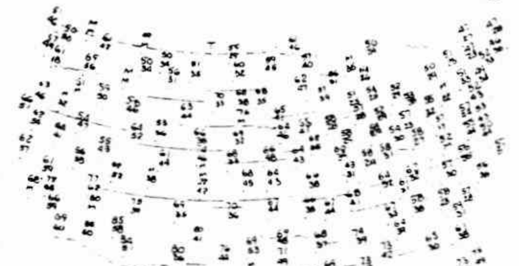

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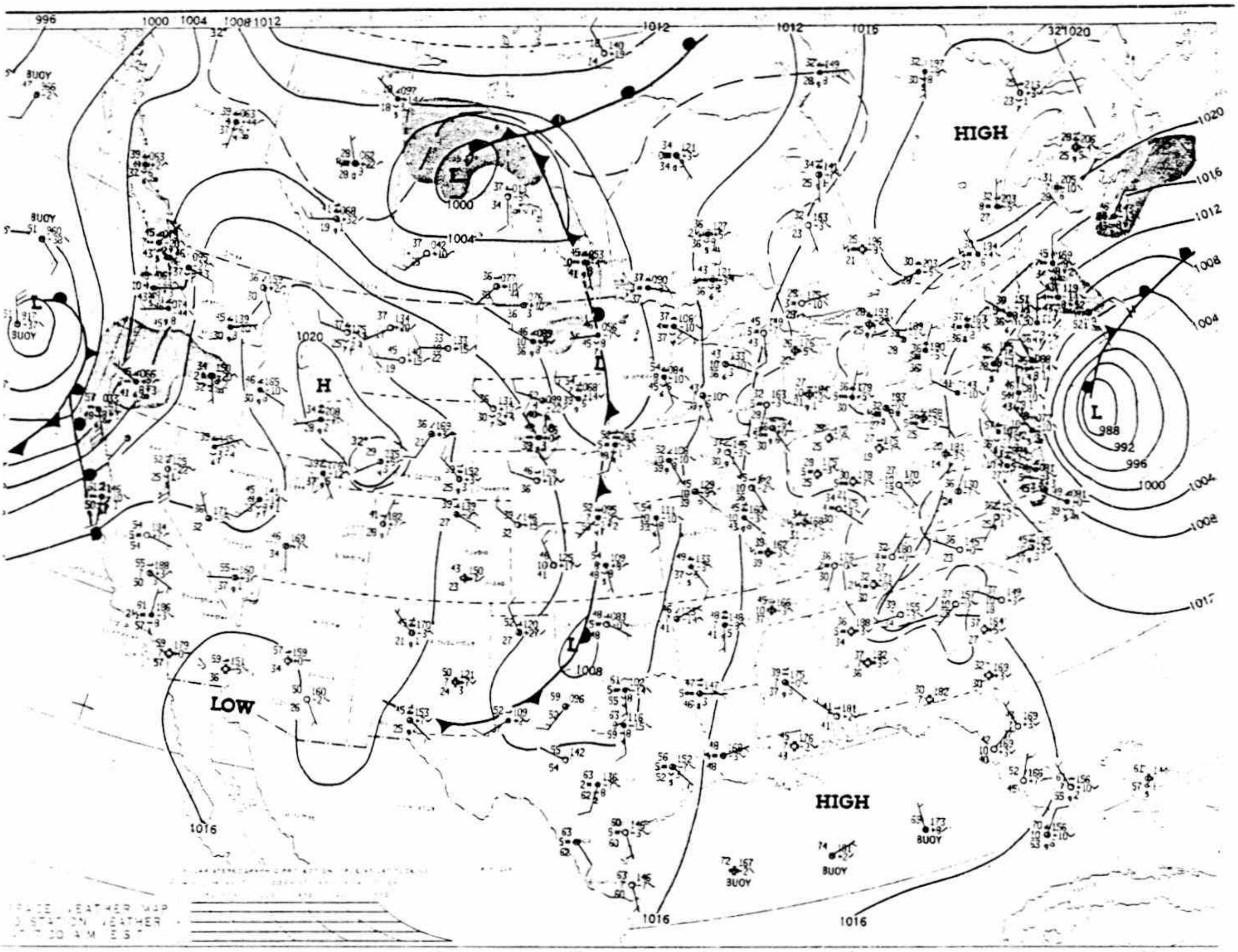
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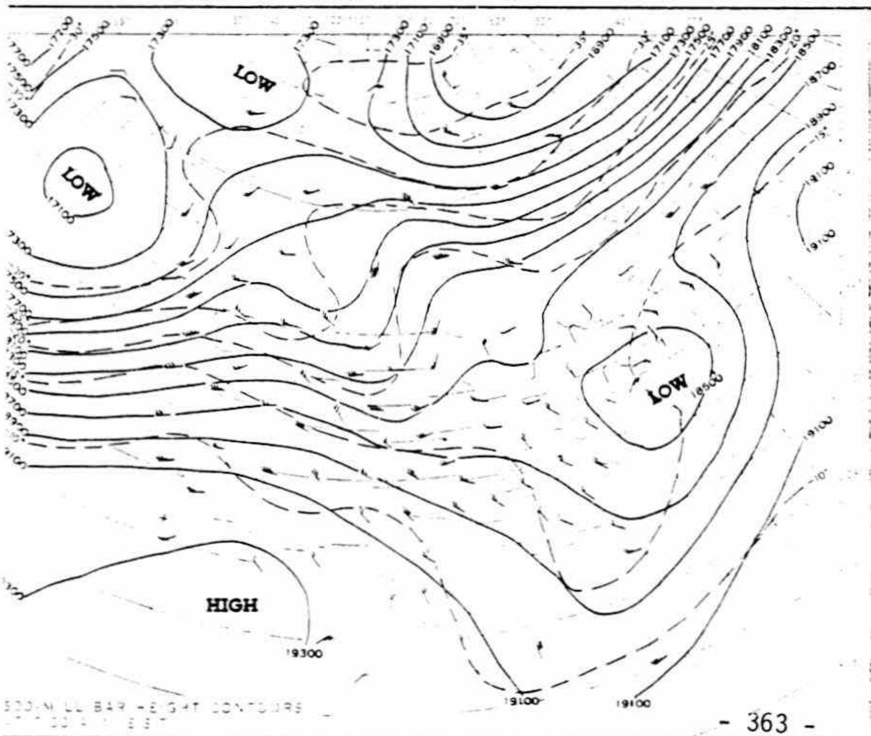
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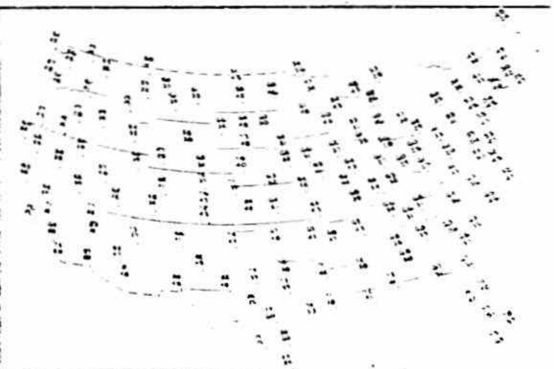

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Proceedings : 29th Ontario
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